DOCUMENT RESUME

ED 183 413 SE 030 322

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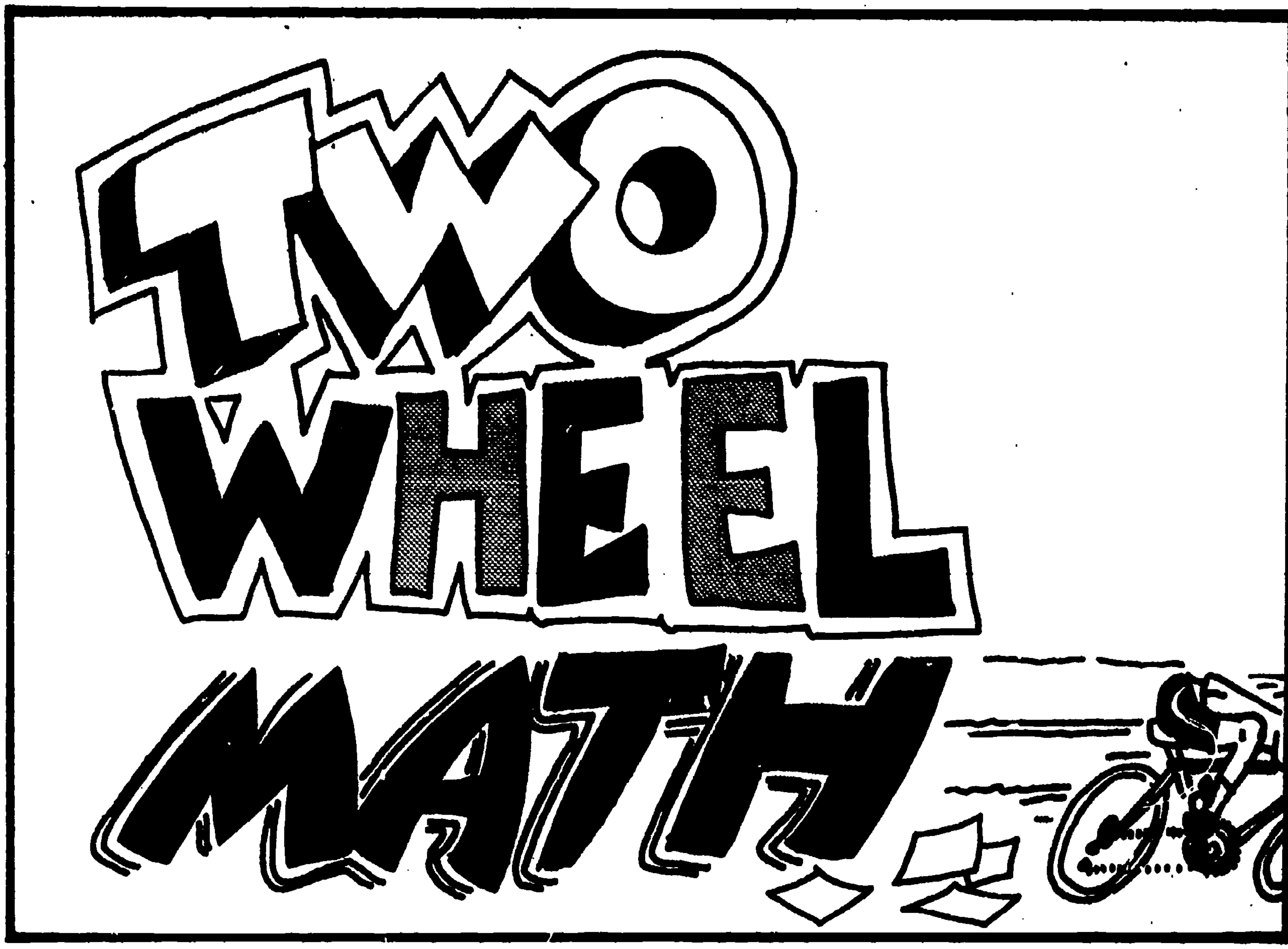
TITLE Two Wheel Math: An Application Module.
INSTITUTION Regional Center for Pre-Coll. Mathematics, Denver, Colo.
SPONS AGENCY National Science Foundation, Washington, D.C.
PUB DATE 74
GRANT NSF-GW-7720
NOTE 56p.: For related documents, see SE 030 304-321

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS *Activities: *Bicycling: Energy: Geometric Concepts: *Learning Laboratories: *Mathematical Applications: Mathematics Curriculum: *Mathematics Instruction: Motivation: Physics: Ratios (Mathematics): Secondary Education: *Secondary School Mathematics: Worksheets

ABSTRACT

This unit is designed to be used primarily by students who have some interest in bicycles. It is intended to draw them into mathematical thinking in an interesting way. This unit is laboratory oriented. It will be necessary that the student have access to a bicycle in the classroom for several of the exercises (unless they are done primarily at home). Some of the activities should be done out on the street while riding, and they are referred to as home-play assignments. Others are strictly pencil-and-paper exercises. Most, however, require data gathering from the bicycle. Included is a statement of many of the more obvious behavioral objectives of this module. It cannot be over-emphasized, however, that the primary objective of this unit is that the student increase his/her enthusiasm for mathematics and his/her understanding of how mathematics can give an enriching insight into ordinary things around us. (Author/MK)



An Application Module

by

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A Publication of

The University of Denver
Mathematics Laboratory
Regional Center for
Pre-College Mathematics

Dr. Ruth I. Hoffman, Director

This material was prepared with the support of
the National Science Foundation Grant #GW-7720.

2

186

Overview

This unit is designed to be used primarily by students who have some interest in bicycles. Hopefully, it will draw them into mathematical thinking in an interesting way. A student who is not inclined toward bikes should not be forced to do this unit or it may destroy a possible future interest in both bikes and math. If the students learn only one thing, namely that mathematics is an aid to understanding and appreciating some of the things around them, the work will not have been in vain.

This unit is laboratory oriented. It will be necessary that the student have access to a bicycle in the classroom for several of the exercises (unless they are done primarily at home). This feature alone should add a spark of interest and novelty and should not be eliminated if at all possible. Several students can work on a single bicycle, however, without reducing their individual benefit from the work.

Some of the activities should be done out on the street while riding, and they are referred to as home-play assignments. Others are strictly pencil and paper exercises. Most, however, require data-gathering from the bicycle.

There is not a specific order in which most of the activities should be done, except worksheets with the same number as an activity sheet should be done following the activity. A few cards draw on concepts developed in a previous card, and it is indicated on a card when some previous card should have been done first.

The student should be freely allowed to find answers in the answer key, but only after some attempt has been made to get the solution through the help of another student or the teacher. The problems are designed for slow, careful thought and experimentation, and this should be emphasized. The student should not feel inhibited about asking questions concerning them.

Included is a statement of many of the more obvious behavioral objectives of this module. It cannot be overemphasized, however, that the primary objective of this unit is that the student increase his/her enthusiasm for math and his/her understanding of how math can give an enriching insight into ordinary things around us.

Activity #'s 13 and 15 would be especially valuable to students interested in ecology, energy and efficiency, even if they have no particular interest in the mechanics of bicycles.

Objectives

1. The student can name components of a 10-speed bicycle and can point out several measurements that make one bicycle differ from another.
2. The student can point out the leverage principles involved with the four leverage-operated components of the 10-speed and can calculate the mechanical advantages of them.
3. The student can describe the geometrical properties of a bicycle frame and wheel that make it strong.
4. The student can utilize the concepts of direct and inverse relationships when discussing the variation of two quantities.
5. The student can identify a linear relationship between two quantities and can predict one quantity from the other in such a relationship.
6. Given two numbers, the student can find their ratio, and can list a set of ratios in order.
7. The student can define a parallelogram and its diagonal, and describe how a 10-speed uses these in its operation.
8. The student can find, use, and describe a gear ratio and gear number on a 10-speed.
9. The student can measure angles and lengths on a bicycle frame.
10. Given two lines with a transversal cutting them, the student can perform measurements to determine whether they are parallel.
11. The student can define a trapezoid and determine by measurement whether a figure is a trapezoid.
12. The student can define and measure revolutions per minute of a turning object.
13. The student can make non-mathematical conclusions from mathematical statistics.
14. The student can substitute numbers into a formula involving multiplication and squaring.
15. The student can translate points from a graph into numerical information.
16. The student can compare joules, watts, calories, Calories, and horsepower, and can use these terms to compare the energy performance of a bicycle and a car.
17. The student can compare the energy efficiency of some of our transportation devices.
18. The student can name and discuss the three resistance factors that operate on a bicycle, and can calculate them from formulas, given various bicycling conditions.
19. The student can discuss at least six ways that mathematics is directly relevant to the use and manufacture of the bicycle.

Activity Description

Act. #1. Naming bicycle parts

2. Making things strong -- triangles
3. Getting into gear -- wheels and teeth
4. Checking your teeth -- gears
5. Power vs. speed -- gear ratios
6. Revving up -- RPM's at home
7. Gear number -- from gear ratios (#5)
8. Rear Derailleur -- parallelograms
9. Frame geometry -- trapezoids and angles
10. Fright frame for you
11. Leverage
12. How levers save effort
13. Eco-logic
14. Energy talk
15. Efficiency
16. Three bears - rolling friction, airdrag, grade.

Materials

1. 10-speed bicycle
2. Light cardboard
3. Scissors
4. Paper fasteners
5. 8 cm blocks or boxes
6. Metric ruler
7. Graph paper
8. Four cardboard strips 2 cm wide
9. Protractor
10. String and weight
11. Ruler
12. Board - one meter or more long
13. Weight (brick, rock, etc.)
14. Meter stick

Outline

I. Activity Sheet #1

A. Teaching suggestions:

1. A good introductory activity; should take only about 15 minutes.

B. Materials:

1. 10-speed bicycle (Student could get more out of it with a real bike present.)

C. Answers:

1. Top tube, seat tube, down tube, head tube, chain stay, seat stay, fork
2. Hub, rim, tire, (spokes)
3. Free wheel
4. Stem (gooseneck)
5. Lugs
6. Front sprockets (chainwheels), crank, pedals, freewheel, roller.
7. Hub, rim

II. Activity Sheet #2

A. Teaching suggestions:

1. Discuss strength of triangles.

B. Materials:

1. Light cardboard
2. Scissors,
3. Four paper fasteners
4. Bicycle.

C. Answers:

1. When the rear axle is counted, we have a triangle made up of the two chain stays and the axle. The two seat stays and the axle make up another triangle. This gives us five triangles in the basic construction of the bike, and four triangles formed by the hub, spokes and rim from the wheel end view of Activity #2.

2. Rectangles are not as rigid as triangles.
3. In the wheels there are at least 54 triangles formed by the spokes.
4. The triangulated bicycle frame has at least 11 triangles.

III. Activity Sheet #3

A. Teaching suggestions:

1. It is best to have two work together on this, as one is needed to hold the bike while the other pedals.

B. Materials:

1. Two 8 cm blocks or boxes
2. Bicycle

C. Answers:

a) Small front, large rear

b) Large front, small rear

c) Small front, large rear

d) Decreases

e) Increases

f) Decreases

Worksheet #3

Note that any other factors remain constant.

1. a) Directly d) Inversely
   b) Directly e) Inversely
   c) Inversely f) Directly
2. a) Answers will vary.
   b) Answers will vary.
3. Inversely.

IV. Activity Sheet #4

A. Teaching suggestions:

1. Discuss K as constant for the ratio $\frac{T}{D}$
2. Students may need review of plotting points on graph.

B. Materials:

1. Light cardboard
2. Scissors
3. One paper fastener
4. Metric ruler
5. Graph paper
6. Bicycle.

C. Answers: (Worksheet #4, Page

1. Student should notice that $\frac{T}{D}$ is a constant for all chainwheels and sprockets measured.
2. Multiplying the constant by 13 cm gives 32 teeth.
3. Direct.
4. Multiplying 2.4 by 20 cm gives 48.
5. Dividing $\frac{32}{2.4}$ gives 13 cm diameter.
6. The points on the chart should fall in a straight line.
8. Yes, the relationship between diameter and teeth number is linear.

V. Activity Sheet #5

A. Teaching suggestions:

After students complete table, a discussion is helpful.

B. Materials:

1. Bicycle
2. Sprocket chart from Activity #4 is helpful.

C. Answers:

1. Large rear sprocket
2. Small chainwheel

Worksheet #5

In the second, ordered table, the ratios should have been arranged starting with B1 and ending with A5. There will be variations in the middle depending on the bicycle's sprocket sizes. It is common for A's to intersperse with B's in the middle of the chart.

1. In going from left to right in the chart, hardness of pedalling should continuously increase and speed of the rear wheel should continuously increase.

VI. Activity Sheet #6

A. Teaching suggestions:

This activity is intended to be done at home. It essentially involves a timing and counting exercise for the purpose of self-rating. Most students will conclude that pedalling faster in a lower gear works better than pedalling slower in a higher gear to go up a hill. Some might conclude the opposite while using 5th and 10th gear on a level stretch, but the general consensus of professional bicyclists is that always using the lowest gear possible with maximum spin is the most comfortable method.

B. Materials:

1. Bicycle

VII. Activity Sheet #7

A. Teaching suggestions:

1. The exercises on cadence (worksheet and activity) are for good students; others will need help.

B. Materials:

1. Table of gear ratios from Worksheet #5.

C. Answers:

a) Answers will vary.

b) Answers will vary.

c) Answers will vary.

d) Should be answered something to the effect that steep hill climbing should be done with the B chainwheel; shallow hill climbing can be done with either the B chainwheel and higher numbered sprockets on the A chainwheel and lower numbered sprockets; flatland or downhill can be done with the A chainwheel. It should be emphasized, however, that combinations B5 and A1 should not be regularly ridden because of extreme angles on the chain and the stress and wear on the small sprocket that B5 creates.

Worksheet #7

1. 24.8 km/hr
2. 12.4 km/hr
3. 1 is the double of 2
4. 104, 52
5. The same.
6. Letourners gear ratio is $\frac{57}{6} = 9.5$ so his gear number is $9.5 \times 27 = 256.5$. One-third of his 108.52 m.p.h speed is 36.2 m.p.h., also in the chart. The closest entry in the chart to 36.2 along the 86 row is 35.9 and this corresponds to 140 r.p.m. which is the answer, as close as the chart can show.

Home Activity #7

1. One possible method is to ride at a pre-set R.P.M., say 75 r.p.m., and list on the handlebar chart the m.p.h. corresponding to each of your gear numbers for 75 r.p.m. (from the chart.)

VIII. Activity Sheet #8

A. Teaching suggestions:

All of the shapes made by distorting the figure have two pairs of parallel sides; i.e., parallelograms.

B. Materials:

1. Four cardboard strips 2 cm wide (two are 20 cm long and two are 10 cm long).
2. Four paper fasteners
3. Metric ruler
4. Bicycle.

C. Answers:

1. Longer
2. Smaller
3. The two vertical sides swing to the right while the bottom bar remains horizontal.
4. The derailleur works by having the moveable cable connected across the diagonal of a parallelogram. Pulling the shift lever shortens this cable and pulls the derailleur rollers toward the wheel.

IX. Activity Sheet #9

A. Teaching suggestions:

1. May need to discuss "soft" and "stiff" rides.

B. Materials:

1. Protractor
2. String and weight
3. Ruler
4. Bicycle

If the answer for $\angle$ b from the chart disagrees with the answer from the protractor, the chart answer is probably more accurate because the A - B measurement would have to be off by .5 cm to cause $\angle$ b to be off by .5 degree. Geting even to the nearest degree with the protractor would be more difficult.

C. Answers:

1. The seat tube parallels the head tube only if $\angle$ a = $\angle$ b exactly (less than 1/2 degree descrepancy).
2. Yes, if the seat tube parallels the head tube exactly.
3. The more the bike is over the front wheel, the more you feel the bumps.
4. The more the front wheel is out in front of the bike (smaller $\angle$ a) the more spring on bumps.
5. Answer is conclusive but would probably make the bike shorter and hence stiffer on the bumps (see Activity #9). The head could still be slanted enough to make the fork ride soft, however.

X. Activity Sheet #10

All of this activity simply discusses the student's own measurements of his/her bike.

XI. Activity Sheet #11

A. Teaching suggestions:

1. Emphasize to the students that if a lever reduces the force necessary to move a load, the price you pay is having to move the lever farther than the load moves.

B. Materials:

1. Ruler
2. Bicycle

C. Answers:

1. a) The load and the force are at the same place.

b) The lever cannot move.

c) The lever is not rigid.

2. Up

3. Down

4. I. The fulcrum is the hole in the handle; the load is the cable, which gets pulled from a mount in the handle when the handle is raised. Hence the fulcrum is at the end.

II. The fulcrum is the bolt near the center of the arm, and the load is the pressure of the brake shoe against the rim.

III. The fulcrum is the hole in the handle and the cable meeting the lever at the bottom is the load. The lever is moved from the top. Hence the fulcrum is near the middle.

IV. The fulcrum is the center of the chainwheel and the load is the pull of the chain to the rear wheel. Hence, the load is between the moving force (pedal) and the fulcrum.

XII. Activity Sheet #12

A. Teaching suggestions:

1. Notice in Example d - m is the total length of the lever.

B. Materials:

1. Board - a meter or more long
2. Weight (brick, rock, etc.)
3. Meter stick.

C. Answers:

1. 40 cm

2. 1 kg

3. a) $\frac{8}{3}$ kg

b) 40 cm

c) 60 kg

d) 90 kg

e) 36-2/3 kg.

4. a) Typical values of $\frac{m}{n}$ for these levers are:

I. $\frac{12}{2.5} = 4.8$

II. $\frac{7.5}{4} = 1.9$

III. $\frac{7}{1.2} = 5.8$

IV. $\frac{17}{10} = 1.7$

These values vary with the brand of the component.

b) The brake arm II

c) The shift lever III (has highest $\frac{m}{n}$)

d) The brake arm II (has least $\frac{m}{n}$)

5. I. More leverage on the brake handle would require that the handle move more and it would hit the handlebars.

II. More leverage on the brake arm would require that it move more, making the brake handle move more and hit the handlebars.

III. More leverage on the shift lever would require a longer swing of the handle and hence longer to shift.

IV. More leverage on the crank would mean longer cranks which could hit the ground when turning.

XIII. Activity Sheet #13

A. Teaching suggestions:

1. Students may like to publicize similar data and their conclusions.

B. Materials:

None

C. Answers:

1. Since a bicycle can usually travel 16 kilometers with ease, most of the auto trips in the U.S. could be done by bicycle instead.

2. Most traveling to work could be done by bicycle.

3. Americans are far less inclined to use bicycles than any other people.

4. The time that cars save over bicycles is at the expense of a huge energy loss.

5. A bike is a very good investment.

There are other possible statements

5. A bike is a v y good investment.

There are other po ible statements about bicycles that the student could conclude.

XIV. Activity Sheet #14

A. Teaching suggestions:

1. Emphasize the difference between a calorie and a Calorie (1000 calories). A joule or a calorie is a very small unit of heat.

B. Materials:

None

C. Answers: (Approx. value is 1 C = 4000 joules

1. calorie

2. 4 (approximate value)

3. $4000 \frac{\text{joules}}{} \times 4000$ Calories $= 16{,}000{,}000$ joules.

4. $11 \text{ h.p.} \times 746 \frac{\text{watts}}{\text{h.p.}} = 8206 \text{ watts}$

5. $1 \text{ Cal/sec} = \frac{4000}{746} = 5 \text{ h.p.}$

$1 \text{ h.p.} = \frac{1}{5} \text{ Cal/sec.}$

Worksheet #14

1. $660 \text{ Cal} \times 4000 \frac{\text{joules}}{\text{Cal}} = 2{,}640{,}000 \text{ joule}$

$\frac{2{,}640{,}000 \text{ joules}}{373 \text{ j./sec.}} = 7078 \text{ sec.} = 118 \text{ min.}$

or just about 2 hours.

2. $\frac{24 \text{ km/hr}}{60 \text{ min/hr}} = \frac{1 \text{ km}}{x \text{ min}}$; $24x = 60$

$x = \frac{60}{24} = \frac{5}{2}$ min $= 2\frac{1}{2}$ min. or

150 sec.

12.6 Cal = 50,400 joules in 150 sec

which gives $\frac{50,400}{150} = 336 \frac{\text{joules}}{\text{sec}}$;

i.e., 336 watts, or about like a 300 watt bulb.

3. $\frac{48 \text{ km}}{60 \text{ min}} = \frac{1 \text{ km}}{x \text{ min}}$; $48x = 60$;

$x = \frac{60}{48} = \frac{5}{4}$ min or 75 sec.

1500 Cal = 1500 x 4000 = 6,000,000 joules in 75 sec; i.e., 48,000 joules/sec =

80,000 watts or 400 200-watt bulbs.

4. A good conclusion from these figures is that we should ride bicycles whenever possible. Other conclusions are possible too.

XV. Activity Sheet #15

A. Teaching suggestions:

1. It might be well to discuss N^{-a} with class.

2. After completing questions, it would be interesting to simply read chart up from bottom in order of decreasing efficiency.

B. Materials:

None

C. Answers:

a) $10^{-4} = \frac{1}{10^4} = \frac{1}{10000} = .001$

b) .001 - .0001 = .0009

So add .00045 (half of .0009) to .0001 to get .00055.

c) Heavier

d) None

e) 10 kg

f) 10^{-4} kg; .000055 kg; 4 kg;

g) $1.5 \frac{\text{cal}}{\text{gm-km}}$

h) $.8 \frac{\text{cal}}{\text{gm-km}}$

i) $.7 \frac{\text{cal}}{\text{gm-km}}$

j) $.6 \frac{\text{cal}}{\text{gm-km}}$

k) $.15 \frac{\text{cal}}{\text{gm-km}}$

l) person on a bicycle.

XVI. Activity #16

A. Teaching suggestions:

1. Discuss how effects of the three bears can be reduced.

B. Materials:

None

C. Answers:

1. Answers will vary depending on each student's weight.

Example: If bike + rider = 80 kg,

R = .01 x 80 kg = .8 kg (dirt)

R = .004 x 80 kg = .32 kg (paved)

R = .002 x 80 kg = .16 kg (track)

2. Answers vary with student's weight.

Example from figures above:

.32 kg + 20% = .32 kg + .20 (.32 kg)

= .38 kg.

3. Answers will vary. Example:

.8 kg + .2 (.8 kg) + .2 (.8 kg) = 1.1 kg.

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1. $G = \frac{20\ m}{500\ m} - \frac{1}{25} = .04 = 4\%$ grade

2. $G = \frac{3700\ m}{80000\ m} = .046 = 4.6\%$

3. 11 km x .07 = .77 km = <u>770 m</u>

Answer to next calculation will vary. If bike + rider = 80 kg, then H = .07 x 80 = <u>5.6 kg</u>

4. You: H = .05 x 80 = 4 kg

Friend: H = 4 kg = x .70 or

x = .057 = 5.7% grade.

Activity #16 (Second continued page)

1. Total headwind = 35 mph. Assume average sized rider.

Upright A = .07 x .35 x $(35)^2$ = 30 kg.

Tucked A = .07 x .20 x $(35)^2$ = 17.2 kg.

Resistance saved = 12.8 kg.

2. Average, upright:

A = .07 x .35 x $(30)^2$ = 22 kg.

Small, tucked:

A = .07 x .15 x $(30)^2$ = 9.5 kg.

Difference = 22 - 9.5 = 12.5 kg.

3. R = C x W = 75 x .01 = .75 kg.

Add 20% for underinflated tires (.15) to get .90 kg.

H = G x W = .02 x 75 = 1.50 kg.

A = .07 x .35 x 16^2 = 6.3 kg.

Total = 8.7 kg.

4. Air Drag.

NAMING THE BICYCLE'S PARTS

Activity 1

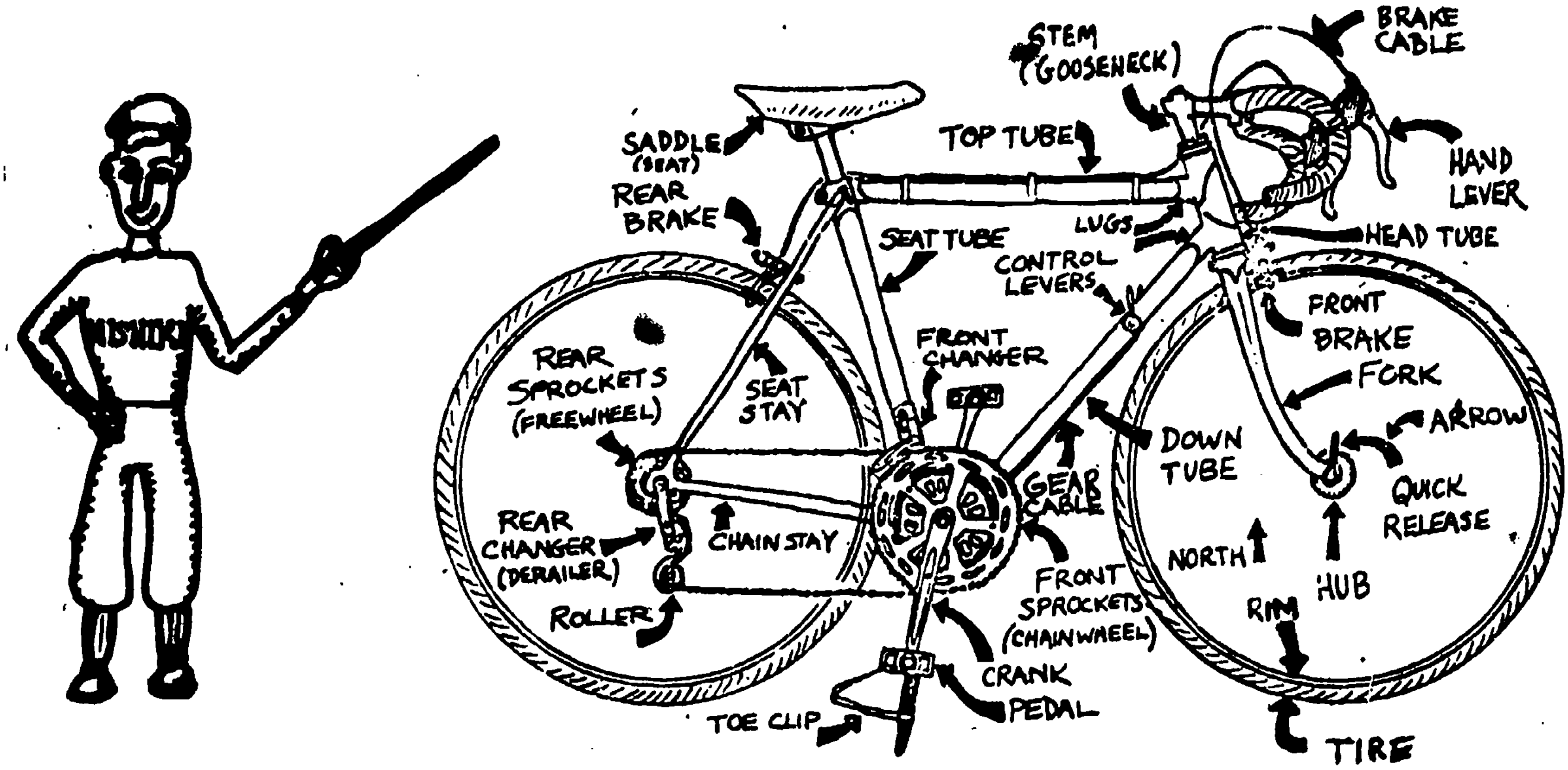


Diagram adapted from ANYBODY'S BIKE BOOK by TOM CUTHBERTSON

JUST TO SEE HOW OBSERVANT YOU ARE...

1. What are all the tubes (pipes) on the bike named? (There are seven different ones.)

2. What are all the parts of the wheel named?

3. The ____________ is made up of five rear sprockets.

4. The ____________ connects the handlebars to the bike.

5. The head tube is held to the top tube by ____________.

6. Name everything you can that goes around when you pedal backwards.

7. A spoke has one end attached to the __________ and the other end attached to the ____________.

For many of the following activities you will need a real 10-speed in front of you. Borrow a friend's if you do not have one, and bring it to class.

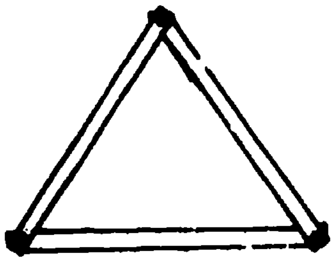
HAVE A COPY OF THIS CARD HANDY FOR LATER CARDS

Materials

4 cardboard strips (about 25 cm long)
4 paper fasteners

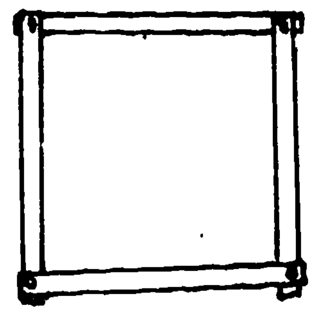
MAKING THINGS STRONG

Activity 2



Connect three of the strips as follows:

Of course this triangle will fall over frontwards or backwards, but jiggle it to see if it will lose its shape. Does it always stay looking like a triangle?

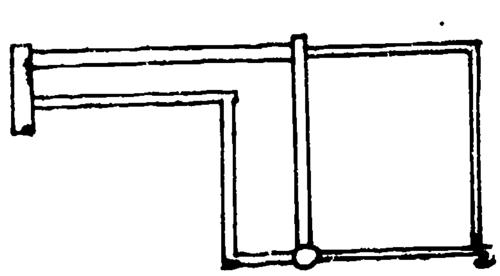


Now pin four of the strips together to make a square. Except for falling frontwards or backwards, does it always look like a square when you jiggle it?

The activities above should have convinced you that the triangle is more than a square. That is why bicycle frames are built mainly out of triangles.

1. Look at a bicycle. How many triangles or near-triangles can you find in the frame? Here is a hint to help you find more: Let the rear axle (the threaded rod that goes through the middle of the rear wheel) be a base of a triangle or two.

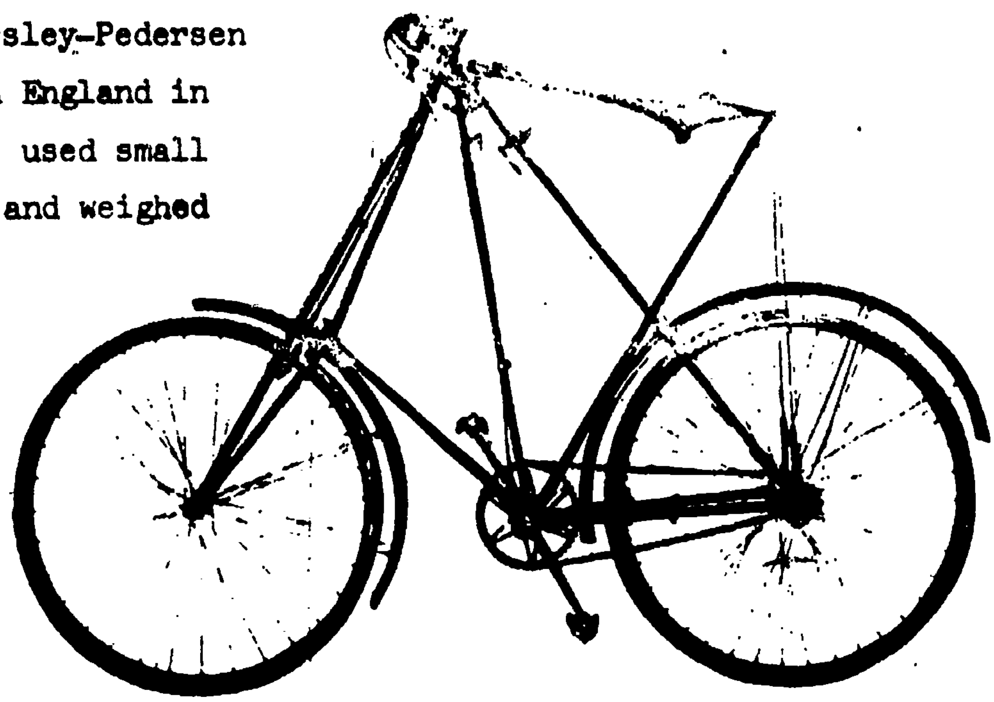
2. Why would a bicycle frame like this be less advisable?



3. Can you see how triangles are used in the wheels as well? (See the picture on the right.) Now look closely at the spoke designs in one of your wheels. How many triangles can you find?

MAKING THINGS STRONG

Here is the Dursley-Pedersen bicycle used in England in the 1890's. It used small diameter tubes and weighed only 23 pounds.



4. This bicycle uses triangles throughout. How many triangles can you find on this bicycle?

NEEDED:
Bicycle
Props or blocks

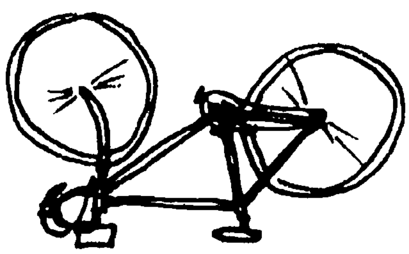
Activity 3

Getting Into GEAR

A bicycle chain is used to transfer the power from the front chain wheel of the bike to the rear sprocket (which turns the wheel and makes you go.) It turns out that the <u>size</u> of the front chainwheel and the <u>size</u> of the rear sprocket both strongly influence your speed and power.

EXPERIMENT

Using your own or a friend's 10-speed, suspend it from ropes fromt he ceiling or have a friend hold up the rear wheel while you pedal. You can also turn the bike upside down if you are careful to prop the handlebars on a piece of wood so the brake cables won't have to support the weight of the bike at the handlebars.



Shift the chain onto the large front chainwheel and the small rear sprocket. Pedal and see how it feels.

Now shift to the small front chainwheel and the large rear sprocket and see how it feels.

a) Which position makes it easier to pedal?

b) Which position makes the rear wheel go faster?

c) Which position makes the pedals move faster?

ANOTHER EXPERIMENT

Leave the chain on the large front chainwheel and pedal while you shift the chain through all five of the rear sprockets. Now answer these questions with "increases" or "decreases".

d) As the size of the rear sprocket increases, the effort of pedalling ____________.

e) As the size of the rear sprocket decreases, the speed of the rear wheel ____________.

f) As the size of the rear sprocket increases, the speed of pedalling ____________.

DEFINITION: If <u>increasing</u> one thing causes another to <u>decrease</u>, we say the two things are INVERSELY related. If <u>increasing</u> one thing causes another to <u>increase</u>, we say the two things are DIRECTLY related.

Getting Into GEAR

1. Write "Inversely" or "Directly" after each of these pairs of things, depending on whether the second changes inversely or directly with the first.

   a) Distance Travelled , Time of Travel ____________

   b) Weight of Jelly Beans , Cost of Jelly Beans ____________

   c) For a draining bathtub:
   Depth of water , Amount of time the water is draining ____________

   d) Population of a square kilometer , Amount of land per person ______

   e) Speed of Travel , Time of Travel ____________

   f) Number of pushups you do today , Number of pushups you can do tomorrow ________

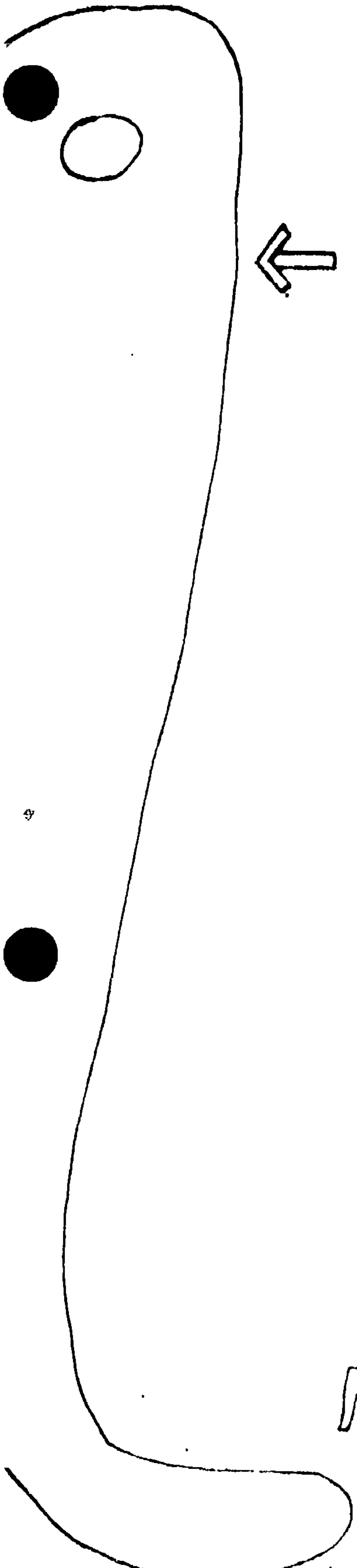
2. a) State two things that vary inversely.

   b) State two things that vary directly.

3. Consider the fraction $\frac{1}{17}$ where n can take on the values 1, 2, 3, ...
Then the size of the fraction varies __________ (directly, inversely) with the size of the denominator n.

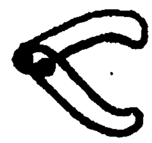
Checking Teeth

Activity 4 (Must do 3 first)

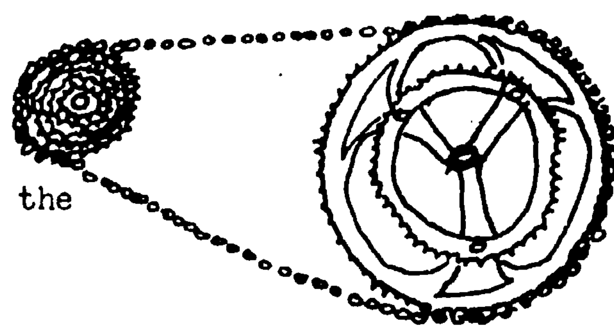


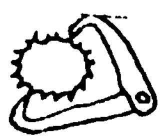
NEEDED: Light cardboard, scissors, paper fastener, metric ruler, graph paper

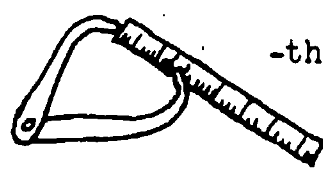
Draw a figure of this size and shape on light cardboard and cut it out with scissors. Now trace around it on another piece of cardboard to make an exact copy and cut that out too. Pin the two together with a paper fastener where the circle is so that they look like this:



NOW you are going to measure the sprockets and chainwheels of your bike by just touching the two extreme teeth with the calipers like this -







-then lay the calipers on a ruler to determine the diameter of the sprocket.

ALSO,

you will count the number of teeth on each of the sprockets you will measure.

NOW fill in a chart like this:

	Diameter	Number of Teeth
Largest sprocket		
2		
3		
4		
Smallest sprocket		
Large chainwheel		
Small chainwheel		

Checking Teeth

Activity 4A

1. For each of the sprockets and chainwheels calculate $\frac{T}{D}$, to the nearest tenth, where T is the number of Teeth and D is the Diameter in cm. What do you notice about your results?

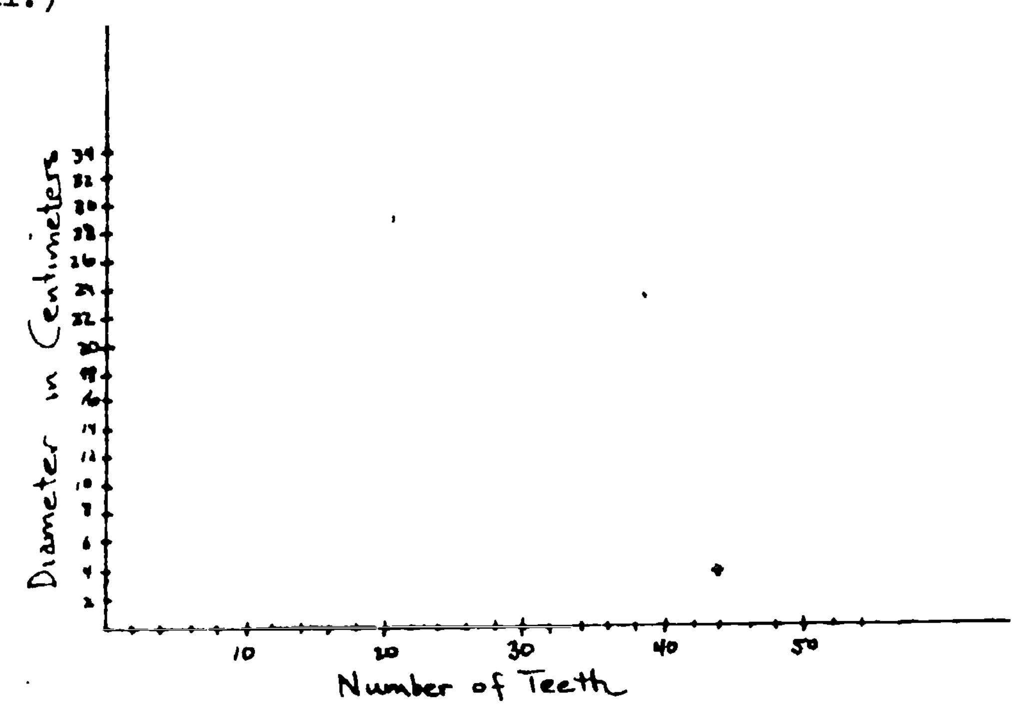
2. Based on your observations in 1, how many teeth would you expect a 13 cm diameter sprocket to have?

3. Is the relationship between the diameter and number of teeth <u>inverse</u> or <u>direct</u>? (See Worksheet 3.)

4. If a chainwheel had a diameter of 20 cm, how many teeth would it have?

5. If a sprocket had 32 teeth, what would its diameter have to be?

6. Let's make a picture of the relationship between the diameter and number of teeth for sprockets and chainwheels. Do this by entering a point at the appropriate place for each of your sprockets and chainwheels (7 points in all.)



7. Check your answer to problems 2 and 4 on the picture above.

8. When the points that show the relationships between things lie on a straight line, the relationship is said to be linear. Is the relationship between diameter and teeth number linear?

EDED:

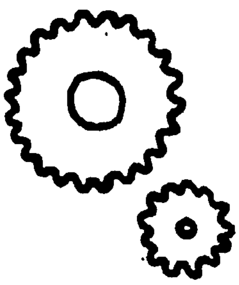
ycle or sprocket
rt from Activity 4

POWER vs. SPEED

Activity 5

Let's fill out a chart that will help us understand gears. If you already filled out the chart on Activity 4, just look it up for the information needed on this chart. Otherwise look at your 10-speed and count the teeth on each sprocket and chainwheel.

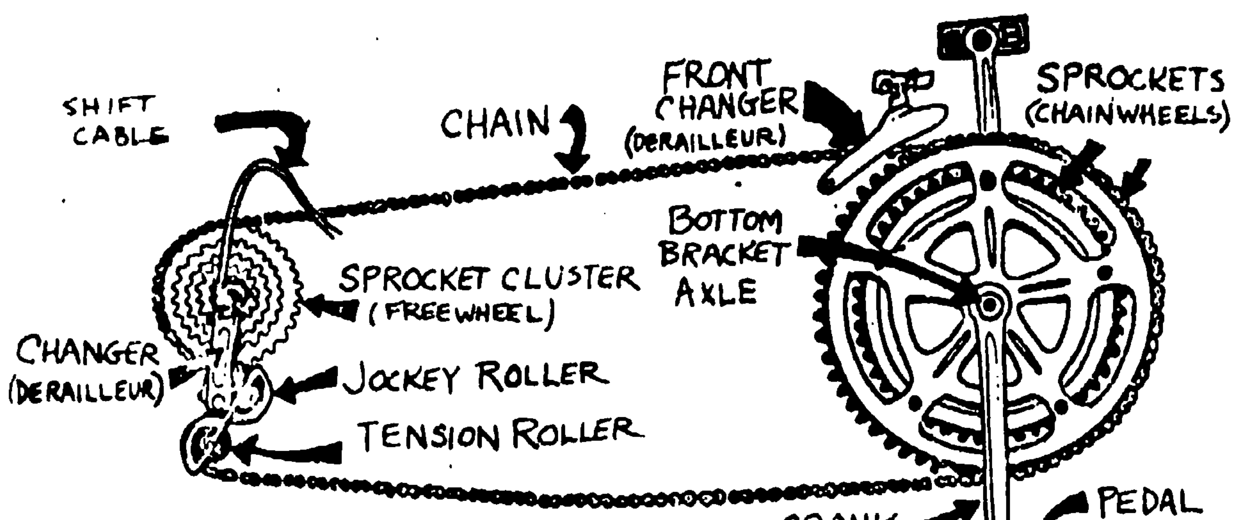
1. Which makes it easier to pedal, the large rear sprocket or the small? Try it and see.



SPROCKET or CHAINWHEEL	NO. OF TEETH
large sprocket (1)	
(2)	
(3)	
(4)	
small sprocket (5)	
lg. chainwheel (A)	
sm. chainwheel (B)	

2. Which makes it easier to pedal, the large chainwheel or the small?

NOTE: From the chart above we can refer to a chainwheel-sprocket combination by a letter and a number, B1, for instance, being the lowest (easiest) gear. Now we are ready to learn about GEAR RATIO. If the chain were running on a front chainwheel that was the same size as a rear sprocket, we would say that the gear ratio was 1 to 1 or $\frac{1}{1}$ or 1 1, or the answer from the division, 1. We will speak here of the answer to the gear ratio division as the "gear ratio".



10 SPEED POWER TRAIN
From Anybody's Bike Book by Cuthbertson

If the front chainwheel had twice as many teeth as the rear sprocket, we would have a ratio of $\frac{2}{1}$ or 2.

To find any gear ratio, do this division to one decimal place:

$$\text{Gear ratio} = \frac{\text{Number of Teeth on Chainwheel}}{\text{Number of Teeth on Sprocket}}$$

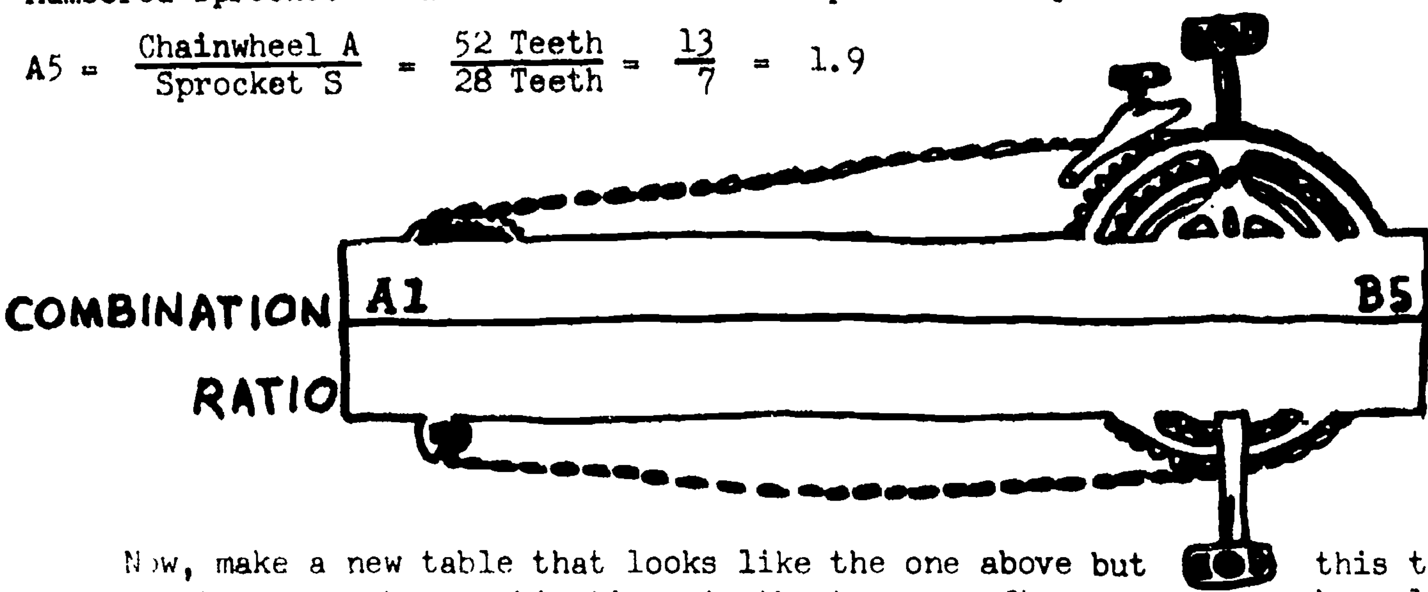
POWER vs. SPEED

WORKSHEET 5

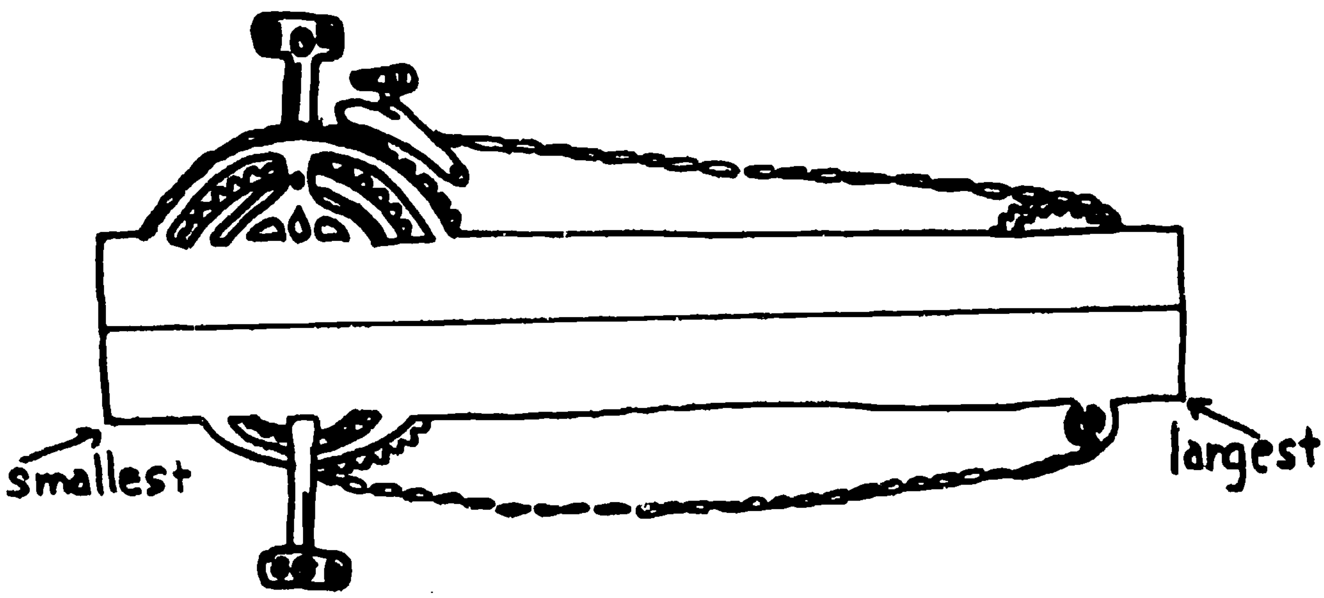
Carefully fill out the following table. In the first line of the table place all possible chainwheel-sprocket combinations by letter and number; for example, A5 is such a combination (and it is the highest or hardest-but-fastest gear.)

Underneath each letter-number combination put the gear-ratio gotten by dividing the number of teeth of the lettered chainwheel by the number of teeth on the numbered sprocket — divide to one decimal place. Example:

$$A5 = \frac{\text{Chainwheel A}}{\text{Sprocket 5}} = \frac{52 \text{ Teeth}}{28 \text{ Teeth}} = \frac{13}{7} = 1.9$$



Now, make a new table that looks like the one above but this time list the letter-number combinations in the top row after you have listed your ratios in order from the smallest to the largest.

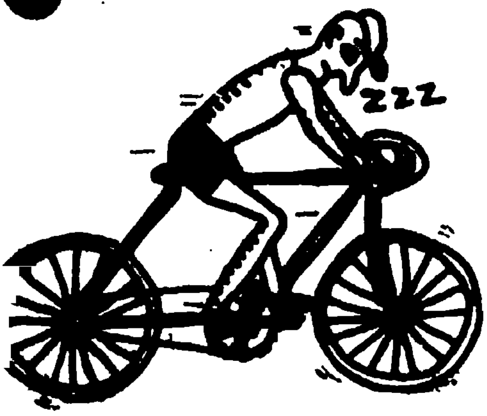


Using this table, suspend your bike from ropes or have a friend hold your rear wheel off the ground while you pedal the bike and shift it through all the possible combinations in the order they appear in the chart above. Try to pedal the same speed all the time.

1. What did you notice about the hardness of pedalling and the speed of the rear wheel as you did this?

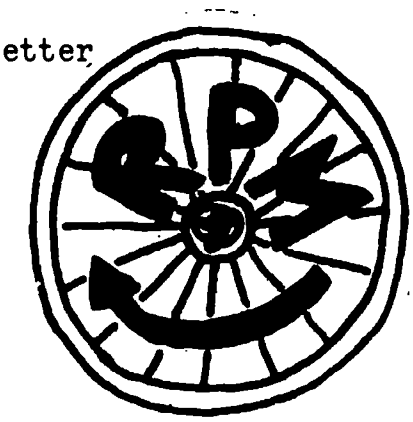
REVVING UP

HOMEPLAY ACTIVITY 6

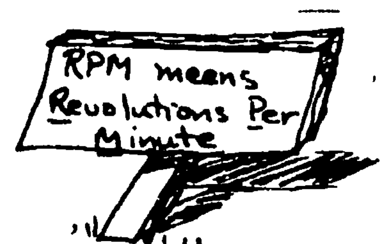


You may think that when you are pedalling it is better shift to the gear that lets you pedal kind of slowly because then it seems like you go fast with little work. Professional bicyclists know different.

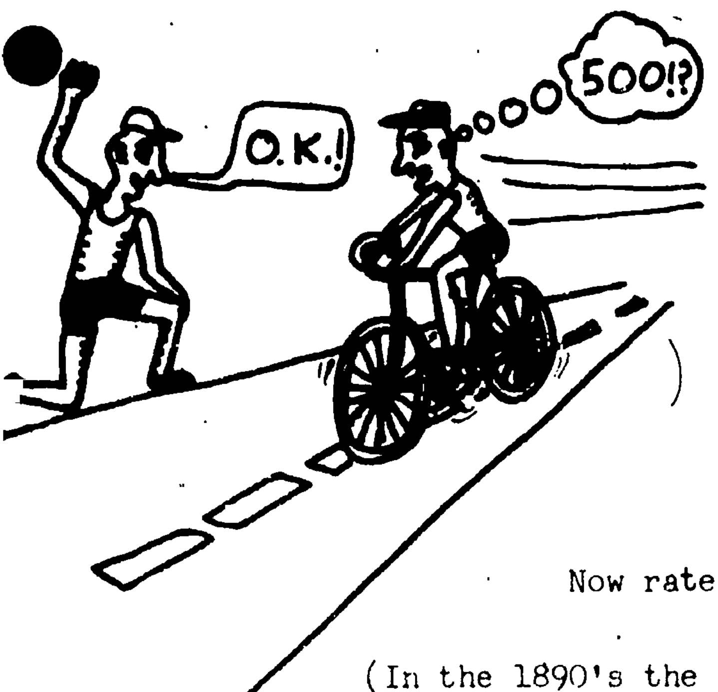
They know it is better to build up your



when you ride; that is, pedal fast whenever you ride.



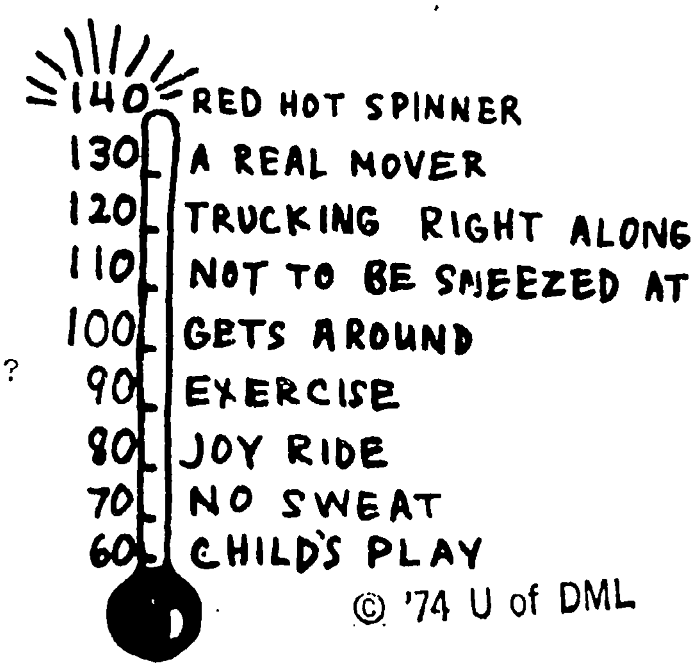
Here is a HOMEPLAY ASSIGNMENT to help you learn about RPM. Have a friend time for one minute while you pedal down the street toward and past him as fast as you can in your lowest gear. (Little front chairwheel to big rear sprocket.) You can also do this if you don't have a 10-speed - say on a 3-speed (use 1st gear) or a clunky no-speed. While you pedal, count how many full pedal revolutions you make (say, from where right foot is down to where right foot is down again). When he shouts "O.K.", the number you are on is the RPM you were pedalling.



Do you see why?

Now rate yourself on this chart:

(In the 1890's the racing champ, Zimmerman regularly pedalled at 140 RPM on his single-speed racing bike.)



Now, pick a hill and pedal up it in low gear so you have to pedal fast, then do the same hill in a higher gear so you pedal slower. Which seems easier? Try the same thing with 5th and 10th gear on a level stretch at medium speed. What do you conclude?

Activity 7 (5 and 6 should be done first)

From your gear ratio you can calculate what professional bicyclists call a

GEAR NUMBER

for each of your gear ratios.

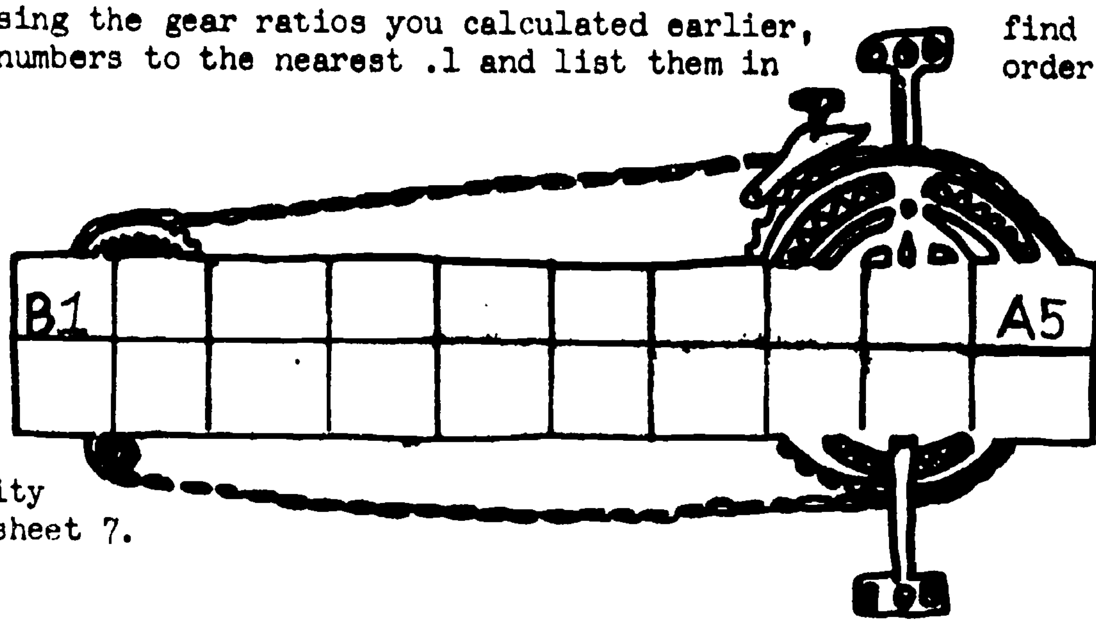
The gear number is commonly given in inches but may eventually be given in meters. We will stick with the very common inch usage here.

GEAR NUMBER = Gear Ratio x diameter of wheel in inches

The common 10-speed wheel is 27 inches but you should measure the diameter of your wheel to the nearest inch to be sure, or see if the marking on your tire says 27 x 1 1/4, or 26 x 1 3/8 (26 inch wheel).

Now, using the gear ratios you calculated earlier, find all 10 of your gear numbers to the nearest .1 and list them in order.

Note:
You will need this chart in Home Activity 7 and Worksheet 7.



35 or less is extremely low - few hills would require it.

100 or more is plenty high for almost any purpose, and any attempts to go faster should be done by increasing pedalling RPM (See Activity 6.)

a) In your list of gear numbers, what is the biggest gap in gear numbers between any two consecutive gears? Where does it appear?

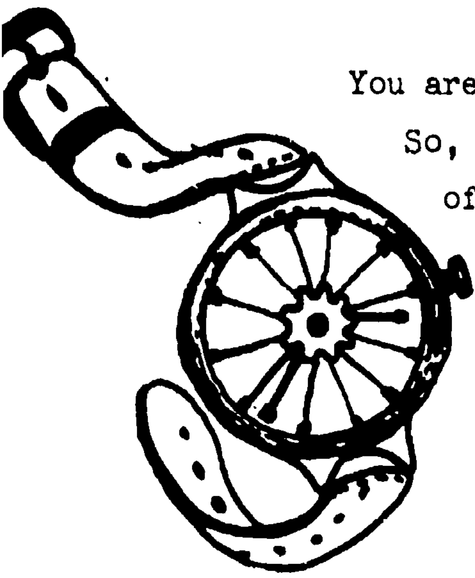
b) Where is the smallest gap between gears?

c) Are any two gear numbers almost the same?

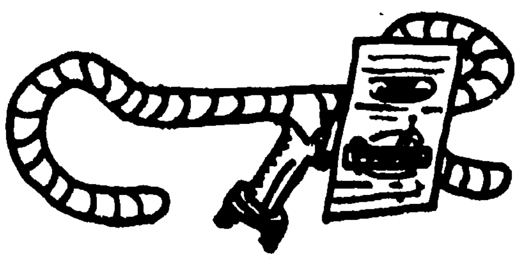
HOMEPLAY ACTIVITY 7
(follows worksheet 7)

CADENCE - A BUILT-IN SPEEDOMETER

A Home Exercise



You are now going to use the cadence chart on Worksheet #7. So, you are about to take a spin on your bike on an open stretch of road, wearing a watch with a second hand, after you have taped or attached to your handlebars the chart of your gear numbers listed in Activity 7.



First look at the chart, scratch your head, and decide how you are going to use it to write information on your handlebar chart so that you can know how fast you are going by counting your RPM (See Activity #6) with the help of the watch. DESCRIBE THE METHOD YOU HAVE FIGURED OUT.

Now go for a ride and try it!

Worksheet 7 (Before home Activity 7)

CADENCE - A BUILT - IN SPEEDOMETER

Take a close look at the cadence chart. To use it, for a given gear, you must know the gear number for that gear (see Activity 7). Find your gear number on the left. The row of figures going across the chart gives how many miles-per-hour you will be going for each of the RPM's listed across the top of the chart. You can convert from miles-per-hour to kilometers per hour by multiplying by 1.58. For example: With a gear number of 70 and pedalling 90 r.p.m., a person will go 18.75 m.p.h. or 29.63 km/hr.

1. How many km/hr could you go with a gear number of 88 and pedalling 60 r.p.m.? ___________ (1 decimal place)
2. If we cut the gear number from 1 in half (i.e., 44) and still pedal 60 r.p.m., we will go _________ km/hr (1 decimal place).
3. How do the answers to 1 and 2 compare?
4. At 130 r.p.m.: 40.4 m.p.h. corresponds to a gear number of ________. Half of 40.4, or 20.2 m.p.h. corresponds to a gear number of ________.
5. So, from the problems above, we can conclude that cutting both the gear number and the speed, the r.p.m. must be __________.
6. Now here is a question for you smart folks: On May 17, 1941, the Frenchman Alfred Letourner went 108.52 m.p.h. behind a racing car (for a windbreak). He had a fixed-gear bike with a 57-tooth front chainwheel and a 6-tooth back sprocket. How many r.p.m.'s was he pedalling?

Hint:

Consult the chart for 1/3 the gear number and 1/3 the speed. The r.p.m. answer you get should be the same as the r.p.m. for his actual speed and gear number.

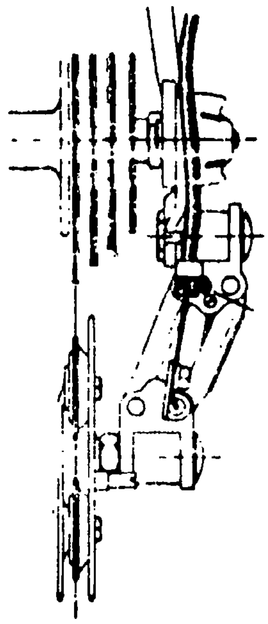
CADENCE CHART

GEAR NO.	REVOLUTIONS PER MINUTE OF THE CRANK ARM										
	60	75	80	90	100	120	130	140	150	160	
38	6.8	8.5	9.06	10.2	11.4	13.6	14.7	15.85	17.0	18.2	MPH
40	7.15	8.95	9.55	10.7	11.95	14.3	15.5	16.7	17.8	19.1	MPH
42	7.50	9.40	10.0	11.25	12.55	15.0	16.30	17.5	18.7	20.1	MPH
44	7.85	9.85	[illegible]	11.8	13.15	15.7	17.0	18.3	19.6	21.0	MPH
46	8.21	10.3	11.0	12.32	13.72	16.4	17.8	19.2	20.5	22.0	MPH
48	8.51	10.72	11.45	12.88	14.32	17.15	18.6	20.0	21.40	22.9	MPH
50	8.94	11.2	11.9	13.4	14.9	17.9	19.4	20.8	22.3	23.85	MPH
52	9.3	11.68	12.4	13.95	15.5	18.5	20.2	21.65	23.2	24.9	MPH
54	9.65	12.1	12.9	14.5	16.2	19.3	20.9	22.5	24.1	25.9	MPH
56	10.0	12.5	13.4	15.0	16.7	20.0	21.7	23.4	25.0	26.75	MPH
58	10.36	12.95	13.82	15.55	17.3	20.7	22.5	24.2	25.9	27.6	MPH
60	10.75	13.4	14.3	16.1	17.9	21.4	23.25	25.0	26.8	28.7	MPH
62	11.1	13.85	14.8	16.6	18.5	22.2	24.0	25.85	27.7	29.6	MPH
64	11.43	14.3	15.3	17.2	19.1	22.9	24.8	26.7	[illegible]	[illegible]	MPH
66	11.8	14.64	15.65	17.7	19.7	23.6	25.6	27.5	29.6	31.5	MPH
68	12.12	15.2	[illegible]	[illegible]	20.3	24.3	26.4	28.4	30.5	32.45	MPH
70	12.51	15.65	16.7	18.75	21.0	25.0	27.1	29.2	31.3	33.4	MPH
72	12.87	16.1	17.2	19.3	21.5	25.7	27.9	30.0	32.2	34.4	MPH
74	13.2	16.58	17.7	19.8	22.1	26.55	28.7	30.9	33.0	35.3	MPH
76	13.6	17.0	18.1	20.4	22.7	27.2	29.4	31.7	34.0	36.3	MPH
78	13.9	17.4	18.6	20.9	23.4	27.9	30.2	32.6	34.8	37.2	MPH
80	14.3	17.9	19.1	21.45	23.9	28.6	31.0	33.3	35.8	38.2	MPH
82	14.62	18.35	19.5	22.0	24.5	29.4	31.8	34.2	36.65	39.1	MPH
84	15.0	18.8	20.0	22.6	25.1	30.0	32.6	35.0	37.6	40.0	MPH
86	15.4	19.2	20.55	23.0	25.75	30.7	33.4	35.9	38.4	41.1	MPH
88	15.7	19.7	21.0	23.6	26.3	31.5	34.15	36.8	39.3	42.0	MPH
90	16.1	20.2	21.5	24.2	27.0	32.2	34.8	37.5	40.2	43.0	MPH
92	16.44	20.6	22.0	24.65	27.45	32.8	35.6	38.3	41.3	43.9	MPH
94	16.8	21.0	22.45	25.2	28.1	33.6	36.4	39.2	42.0	44.9	MPH
96	17.15	21.5	22.95	25.75	28.7	34.3	37.2	40.0	42.8	45.8	MPH
98	17.5	21.9	23.4	26.2	29.25	35.0	38.0	40.8	43.8	46.7	MPH
100	17.9	22.4	23.9	26.8	29.95	35.75	38.8	41.7	44.8	47.8	MPH
102	18.2	22.8	24.4	27.3	30.45	36.55	39.6	42.6	45.7	48.8	MPH
104	18.6	23.25	24.85	27.9	31.0	37.25	40.4	43.4	46.7	49.6	MPH
106	18.9	23.7	25.3	28.4	31.3	37.9	41.3	44.2	47.5	50.6	MPH

CYCLO-PEDIA Cadence Chart. - Calibrated by Professor Paul R. "Pop" Kepner.

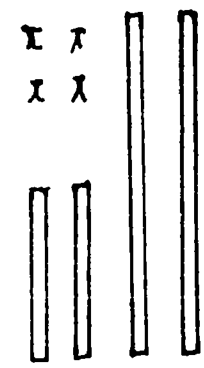
GEOMETRY AND THE REAR DERAILLEUR

Activity 8

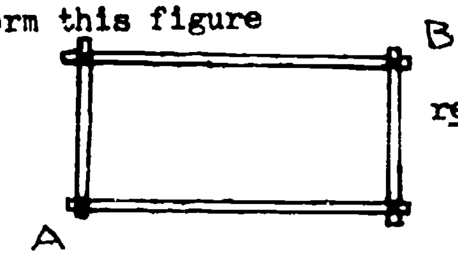


The rear derailleur is that thing on the rear that moves when you move your right shift lever.

To understand how it works we must do some preliminary investigation of the geometric figure known as the parallelogram. For this investigation you will need four 2-cm wide cardboard strips, two of them 20 cm long, and two 10 cm long. Put them together to form this figure



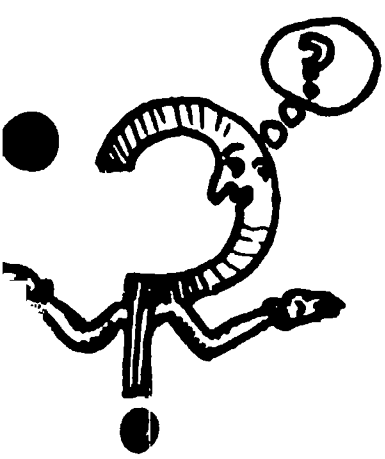
which is a



rectangle, of course.

Note that each pair of opposite sides are parallel.

Parallel means that no matter how far you extend them, they will never meet - they will stay the same distance apart.



Now experiment with the figure this way: Change its shape any way you can as long as the changes you make allow it to lay flat on a table.

Can you get something more diamond shaped?

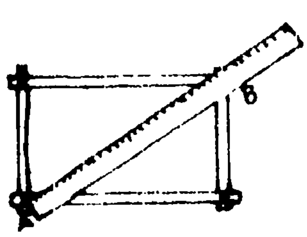
Can you make it so that the area inside is almost nothing?

Do some of the new shapes you made have parallel sides?

Do they all have parallel sides or is there some exception?

All the figures you made are called parallelograms. Why is this a good name for these figures?

EXPERIMENT:



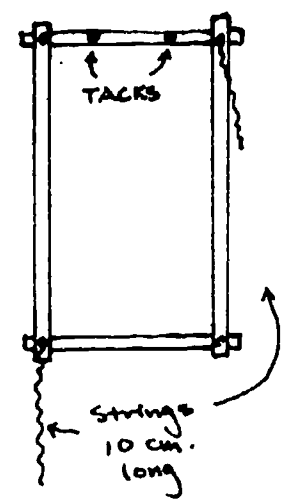
Move your cardboard thing through all of its shapes again, but this time also use a ruler that will measure the distance from corner A to corner B. The segment AB is called a diagonal. How many diagonals are there?

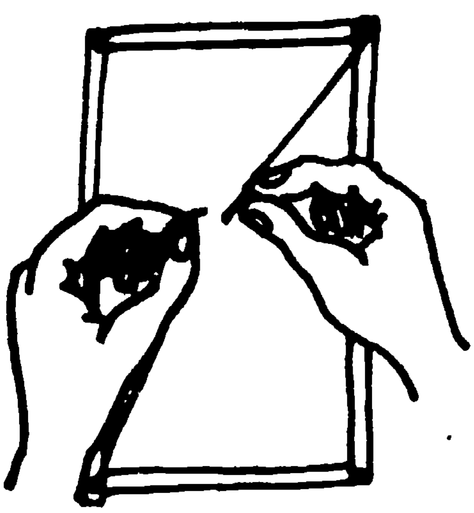
Now make the A to B distance shorter.

1. The shorter the diagonal, the ______________ the other diagonal. (shorter, longer)
2. The shorter the diagonal, the ______________ the area of the figure. (larger, smaller)

geometry and the rear derailleur

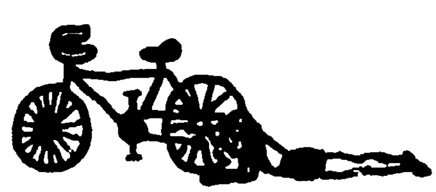
Now we will set up a simple model that shows just how the derailleur works. Take the cardboard rectangle you made and tack one short side to the bulletin board with two tacks like this: Tie two 10 cm strings to the corner fasteners like this diagram.





Pull the two strings together so that their two ends touch and form a diagonal. What happens to the cardboard figure? What part moves when you join the two strings? Is movement to the right or left?

You are now ready to look at the rear derailleur on a bicycle. As a practice let's look at the derailleur pictured on the previous card. It is a SIMPLEX brand derailleur. Look closely - do you see a parallelogram and its four corners? Do you see the cable across its diagonal? If that cable were to shorten, what would happen to the parallelogram; i.e., to the derailleur?



Now look at the derailleur on your bike. Look for a parallelogram by moving your right shift lever only about 2 cm or so back and forth (don't move it more than that without pedalling) while watching the rear derailleur. The parts that are moving should form a parallelogram. (It is a little harder to see this on a Huret derailleur). See if the cable from your shift lever acts as a diagonal for this parallelogram.

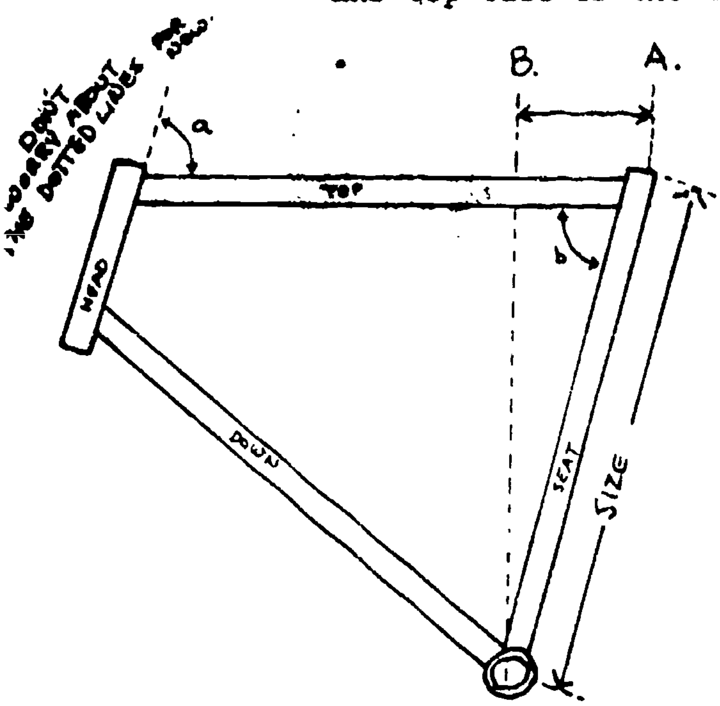
Can you describe now (in geometric terms) how your derailleur works?

NEEDED:

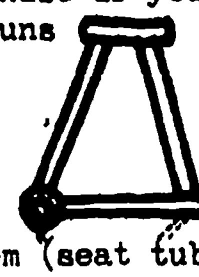
Protractor, string, weight and ruler

FRAME GEOMETRY

The large figure made from the head tube, down tube, seat tube, and top tube of the bicycle frame looks like this. (Be sure where these are on your bike.)



This figure looks almost like a triangle but its not one. Do you recognize what it is? It is easier to recognize if you tilt this card until the seat tube runs along the bottom of the figure.



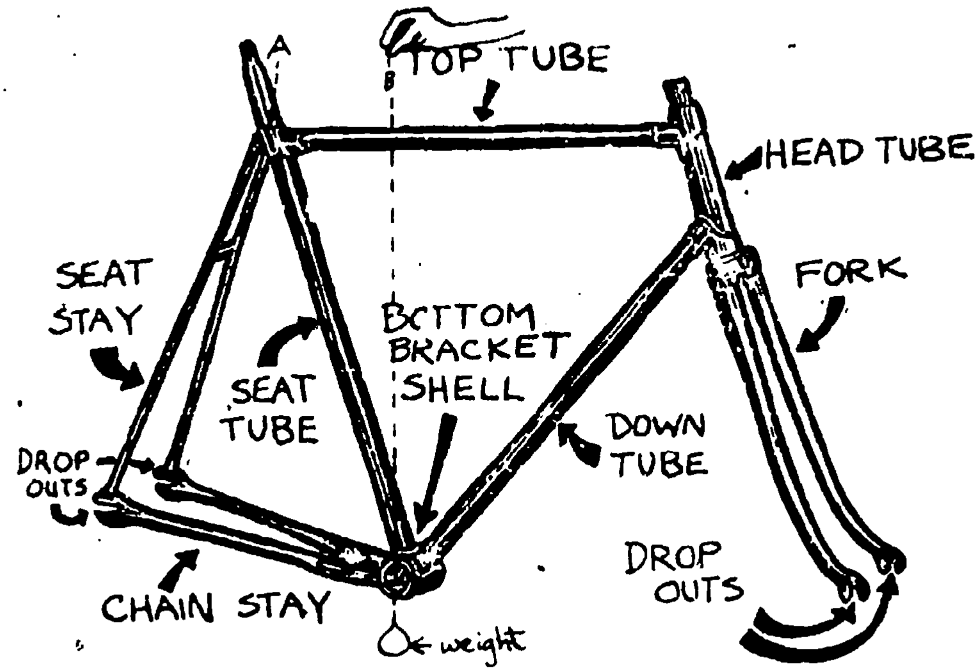
You guessed right - it's a <u>trapezoid</u>, or nearly one. To be exactly a trapezoid, the top (head tube) has to be parallel to the bottom (seat tube). "Parallel" means that no matter how far you extend them, they would never meet.

It is a well-known fact in geometry that if two segments are parallel, then the two angles a and b must be equal and vice versa; if angles a and b are equal, then the two segments (tubes) must be parallel.

The purpose of this activity is to see if your head tube and seat tube are parallel so you will know whether your bike has a perfect trapezoid in it (a nice thing to know)! To do this, we will check in a couple of ways whether a and b are equal angles.

Activity 9
(Continued)

frame geometry



Use this chart to find Angle b.

Size of Bike (in centimeters)	SEAT ANGLE b.					
	72°	72°30'	73°	73°30'	74°	74°30'
	DISTANCE A – B					
55.0	17.0	16.5	16.0	15.6	15.2	14.7
55.5	17.1	16.7	16.2	15.8	15.3	14.8
56.0	17.3	16.8	16.4	15.9	15.4	14.9
56.5	17.5	17.0	16.5	16.0	15.6	15.0
57.0	17.6	17.1	16.7	16.2	15.7	15.2
57.5	17.8	17.3	16.8	16.3	15.8	15.4
58.0	17.9	17.4	17.0	16.4	16.0	15.5
58.5	18.1	17.6	17.1	16.6	16.1	15.6
59.0	18.2	17.7	17.2	16.7	16.3	15.8
59.5	18.4	17.9	17.4	16.9	16.4	15.9
60.0	18.5	18.0	17.5	17.0	16.5	16.0
60.5	18.7	18.2	17.7	17.2	16.7	16.2
61.0	18.9	18.3	17.8	17.3	16.8	16.3
61.5	19.0	18.5	18.0	17.4	16.9	16.4
62.0	19.2	18.6	18.1	17.6	17.1	16.5

CHART AND PICTURE ADAPTED FROM TOM CUTHBERTSON'S BIKE TRIPPING

1. Hang a string with a weight on the end so that it hangs just above the center of your crank.

2. See where the string crosses the top tube. This is B in the picture; mark it with chalk.

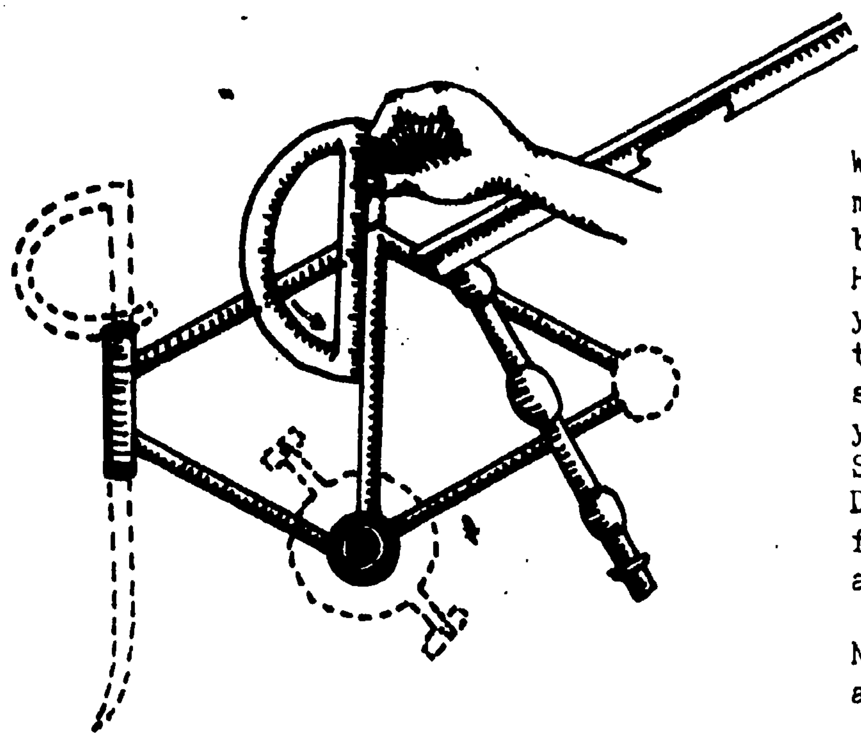
3. Now measure from the center of the crank to the top of the seat tube, as well as measuring from A (center of seat tube) to your point B.

4. Now use the chart by finding A-B distance and bike size on it, then reading the seat angle b.

Seat Angle b 71 °

Activity 9
(2nd Continued sheet)

frame geometry



With your protractor, check your measurement of Angle b by first standing your bike against the wall about 2 meters away. Hold the protractor about 1/2 meter from your face, with your arm braced on a table top and one eye closed. You can stand on one foot with one arm behind your back too, but you don't have to.) Sight the seat angle of your bike frame. Does it agree with the answer you got from the table? If they disagree, which answer can you trust?

Now sight with the protractor to get the angle of the head, Angle a.

a = ______°

NOW,

1. Is the seat tube parallel to the head tube?

2. Does your bike frame contain a perfect trapezoid?

How is your bike made to ride?

3. If your head tube Angle a is near 75°, your bike is made for a "stiffer" ride that feels the bumps. (Imagine the Angle a being 90°, and see if you can tell why it would be <u>very</u> stiff.)

4. If your Angle a is near 72°, it makes a "softer" ride and steering that stays more centered. (Can you tell why? Imagine $\angle$ a = 45° and see if you can see why.)

FOOD FOR THOUGHT

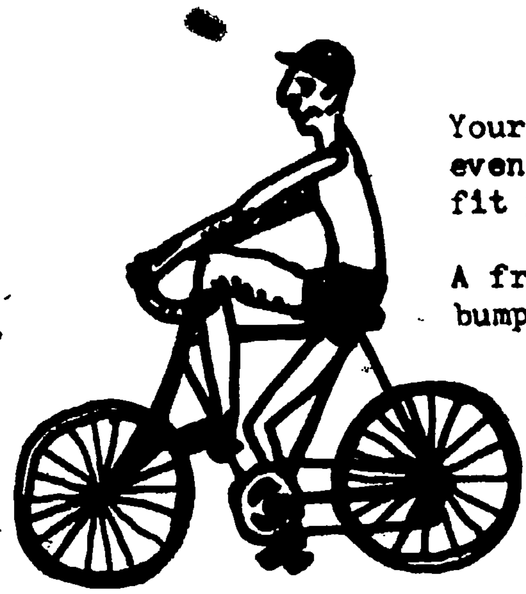
5. If your seat Angle b were less than your head angle, instead of equal to it, would this make it ride "softer" or "stiffer".

Activity 10

THE RIGHT FRAME DIMENSIONS FOR YOU

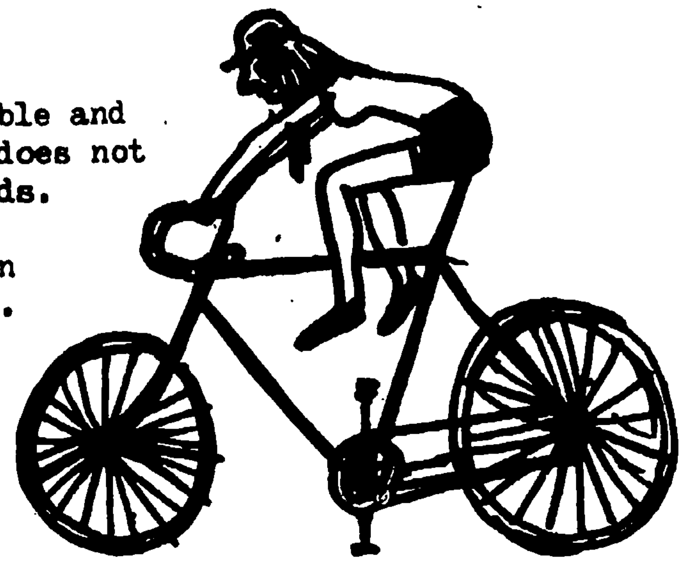
NEEDED: String, 2 meter sticks

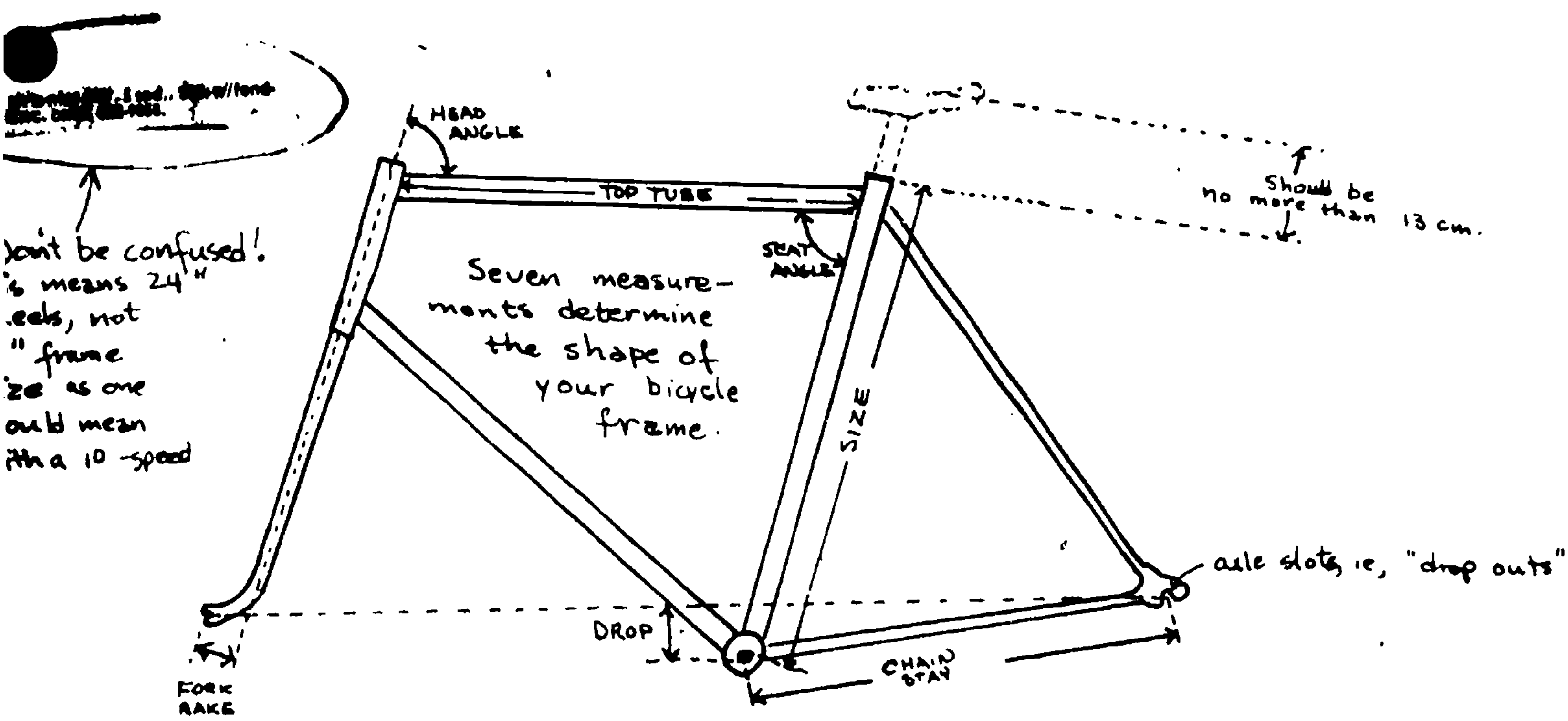
Note: Measurements done on this card are only for 27" wheel diameter (68.5 cm wheel) 10-speed bikes. Use a friend's bike for your measurements, if necessary.



Your riding can be uncomfortable and even dangerous if your frame does not fit your size and cycling needs.

A frame is a shock absorber on bumps and hard pedalling also.





In Activity #9 you measured the Head Angle and Seat Angle. Now record these six measurements, using a string and two meter sticks:

FORK RAKE ______
TOP TUBE ______
DROP ______
SIZE ______
CHAIN STAY ______
WHEEL BASE ______

"Wheel Base" is the distance between the two points where your wheels touch the ground.

"Drop", "Chain stay", and "Size" are all measured from the center of the crank.

"Drop" should be measured from the top of the axle slots.

the right frame dimensions for you

Sit on the floor with your feet tilted to a 45° angle and touching a wall. Measure the distance in centimeters from your crotch to the wall. Subtract 28 cm from this measurement. Your bike SIZE should be within 1 cm of this measurement. (When you buy a bike, a quick check for this is to see if your TOP TUBE just clears your crotch comfortably when you are standing over it, feet flat on the floor.)

WHY THE RIGHT SIZE?

If a frame is TOO LARGE, it can injure your crotch if you have to stop suddenly.

If a frame is TOO SMALL, you have to raise your seat very high. This makes you sit further over the rear wheel, putting too much weight on the rear and not enough on the front, and it makes you bend over too far to reach the handlebars.

WHY FORK RAKE?

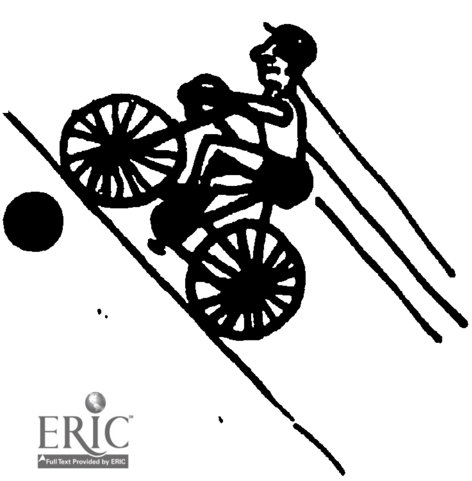
The further the front wheel sits out in front of you, the "softer" the bike rides. Can you see why? So, a 2.5 cm rake makes a "stiff" ride and a 7 cm rake makes a "soft" ride. Activity #9 tells how HEAD ANGLE influences this too.

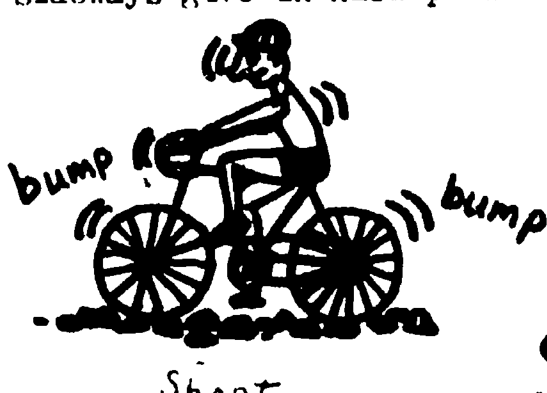
WHAT'S THE DROP FOR?

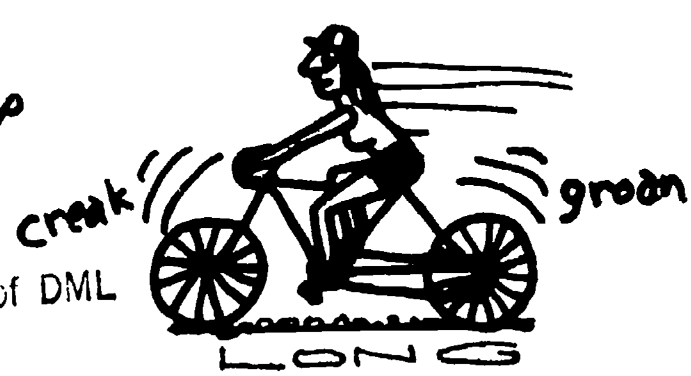
Drop determines how low you sit on the bike and the lower the better, because the higher you sit, the harder it is to balance. But if the bike sits too low at the pedals, you will drag when you turn a corner, and that has caused many bruises! More than 7 cm drop courts trouble.

WHAT ABOUT WHEEL BASE?

The sizes of the CHAIN STAY, TOP TUBE, FORK RAKE, AND HEAD ANGLE all result in either a <u>long</u> or a <u>short</u> WHEEL BASE (usually between 99 cm and 104 cm). A short wheel base gives a "stiff" ride, which shakes the bones more on bumps but holds up under hard uphill pedalling. A long wheel base cushions the bumps but causes "frame whip" or sideways give in hard pedalling conditions.







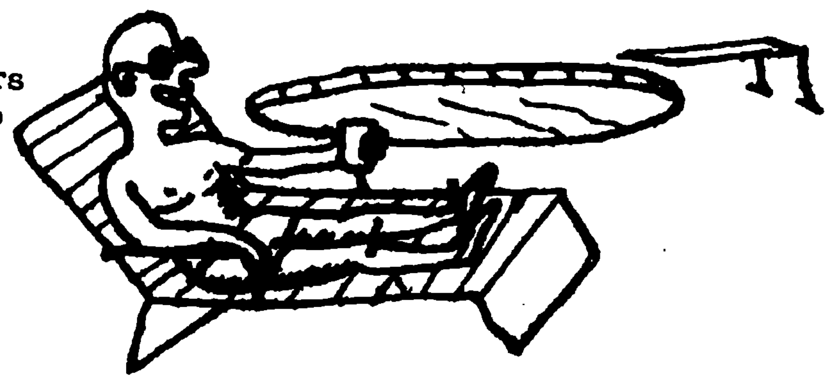
GETTING LEVERAGE ON THE SUBJECT

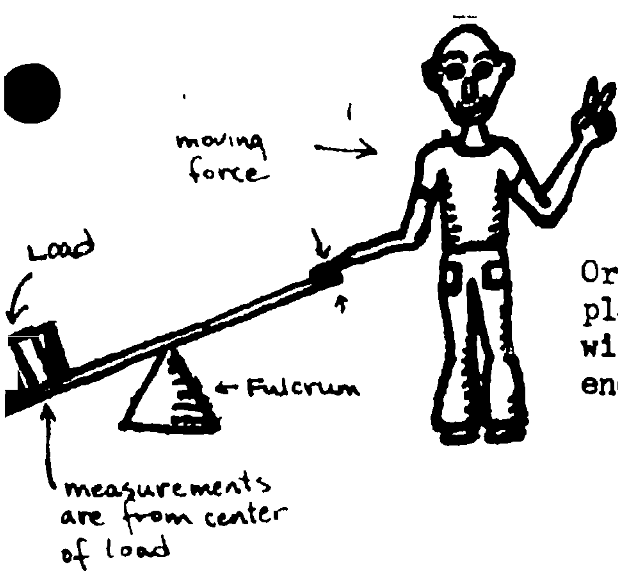
Activity 11

Before you go any further, it is necessary that you understand the principles of

because a bicycle operates on <u>leverage</u>.

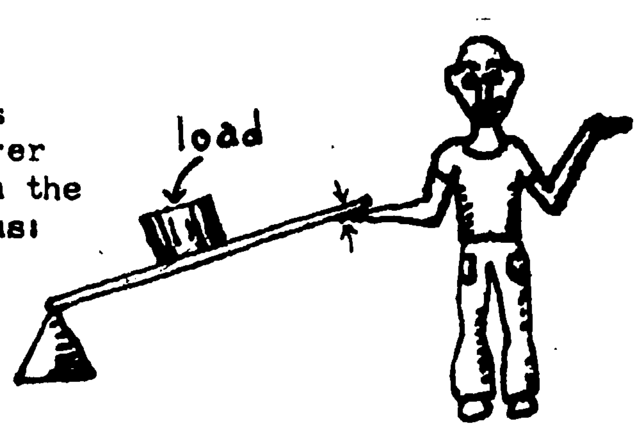
People have known about levers for a long time because they make work easier and you know how people are about that!





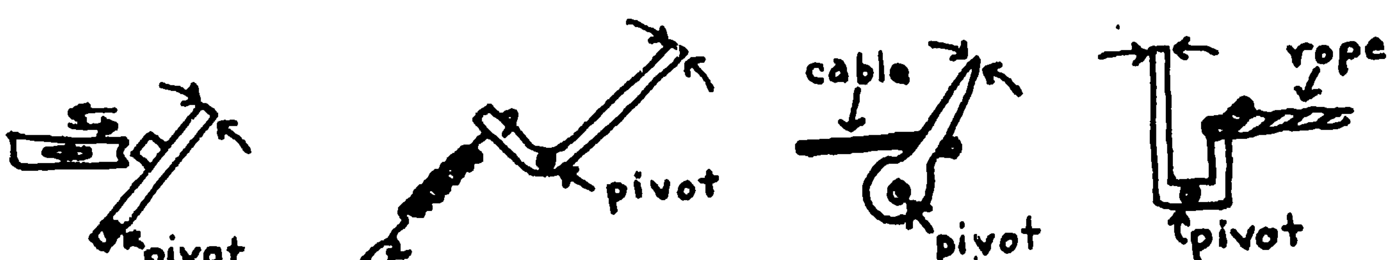
A lever has a fulcrum which is its point of swing, and a load.

Or, sometimes a fulcrum is placed at the end of a lever with a load placed between the end and the mover like thus:



Both arrangements can make it easier to move the load. Furthermore, it does not matter what the fulcrum or lever or load looks like as long as the lever is rigid, can move, and has the load at a different place along it than at the fulcrum or the moving force.

These are levers:



Can you see the loads?

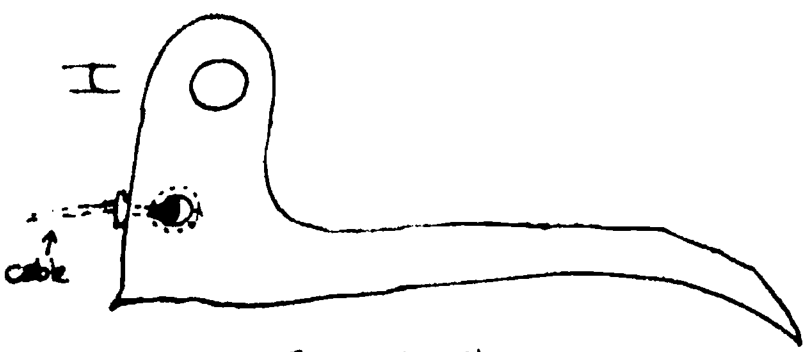
GETTING LEVERAGE ON THE SUBJECT

Needed: Bicycle

1. The following are not levers. Why?

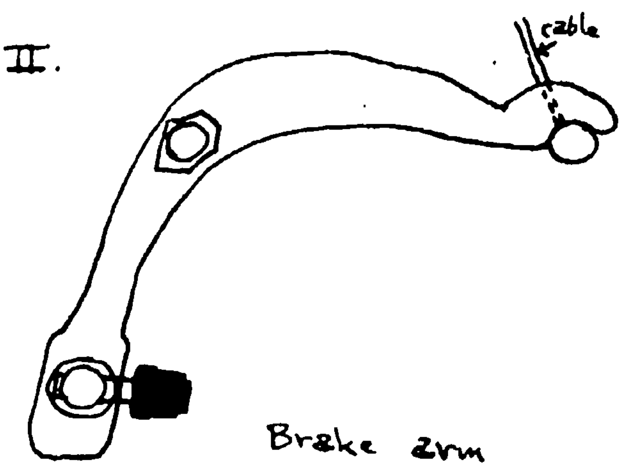
2. If the fulcrum is at the end of a lever and we wish to raise the load up, we move the lever _______ (up, down).
3. If the fulcrum is near the middle of a lever and we wish to raise the load up, we move the lever _______ (up, down).
4. The following are parts from a 10-speed, and all of them are levers. Locate each on your bicycle, or a friend's. Make each one move and notice how it pivots. For each, identify the fulcrum and its position (end or near middle), and identify the load.

I



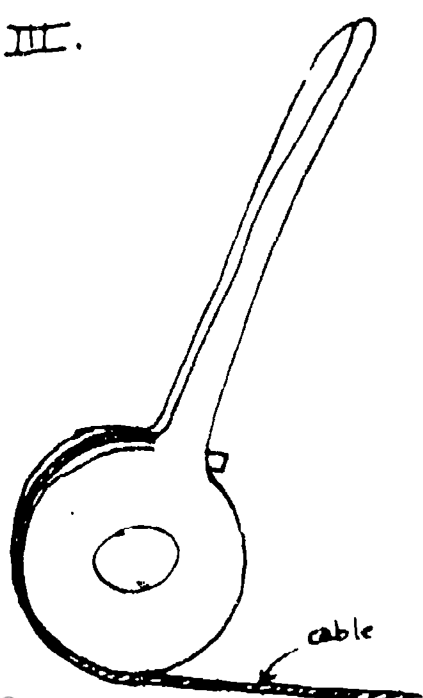
Brake handle

II.



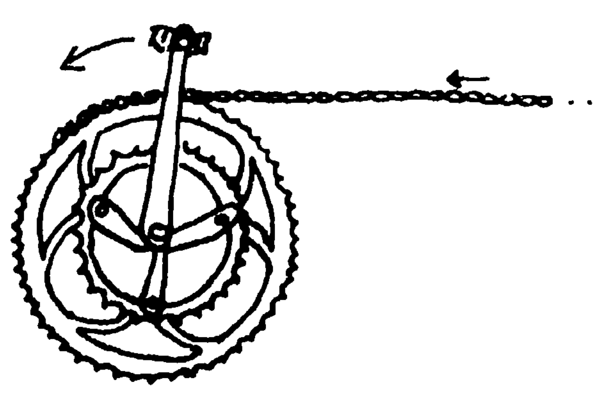
Brake arm

III.



Shift Lever

IV.



Chain wheel & Crank Arm.

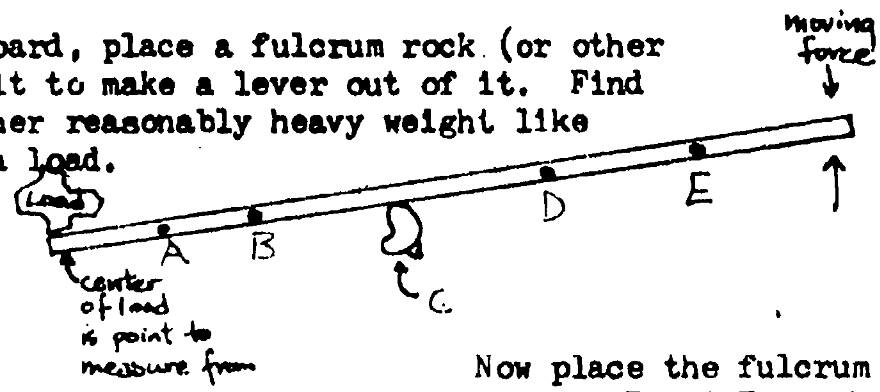
DED:
meter long
more) board
, brick or
like, meter
ick

MORE ON LEVERS

Activity 12
(Must do 11 first!)

Subtitle: How they save effort on your bike

Find a board, place a fulcrum rock (or other bump) under it to make a lever out of it. Find a rock or other reasonably heavy weight like a brick for a load.



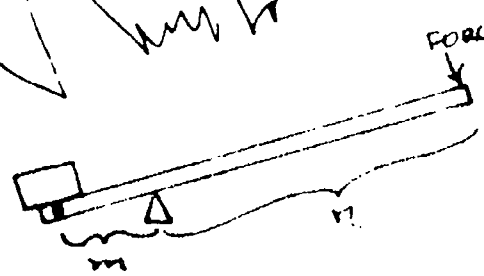
Place the fulcrum-bump at point C (mid-point) and lift the load by moving the lever.

Now place the fulcrum at the points B, then D and E, each time lifting the load by forcing the moveable end down. List the letters A through E in the order of effort (force) exerted in lifting the load. Are you starting with A (the easiest)? You should. Did you notice anything about the direction you had to move the lever to left the weight?

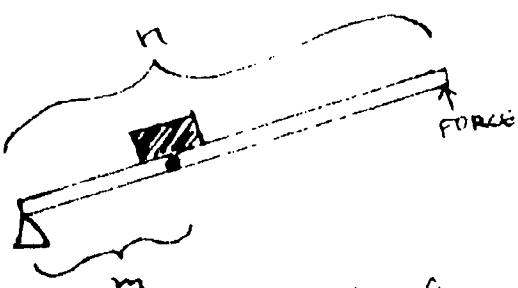
Is it clear to you yet how a lever saves effort?

Now list the letters A through E according to how far you had to move the lever to move the load 10 cm. You should list E first because with fulcrum at E it took very little movement of the lever to make the load move 10 cm.

Mathematicians have figured out a very neat way to describe how much effort or movement a lever saves. They do this with ratios (one number divided by another). Here is how it works:



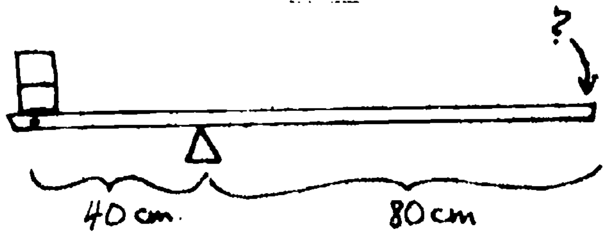
$\frac{m}{n}$ is the fraction of the weight of the load required to operate the lever (move the load).



$\frac{n}{m}$ is the fraction of (or how many times) the distance the load moves that your hand (the force) must move when you operate the lever.

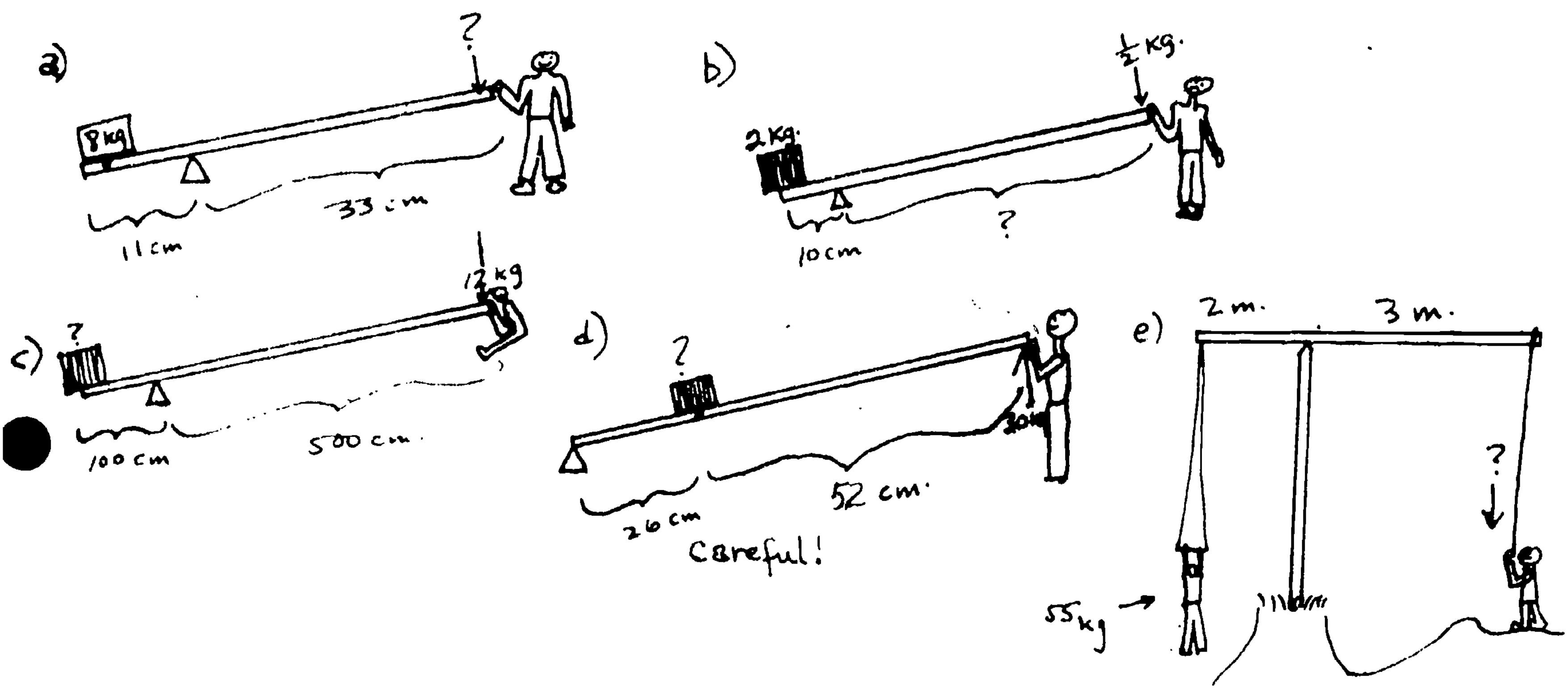
NEEDED: Bike, ruler

1. If your lever allows you to move a load by using force (or weight) equal to only 1/2 the weight of the load, how much must you move your end of the lever to make the load move 20 cm?

2. 

How many kilograms of butter will it take at the end of the lever to balance the load of two kilograms of butter? (Hint: Find $\frac{m}{n}$, reduce to a simple fraction.)

3. In the following pictures, find the missing lengths or weights.



4. For each of the levers found on a bicycle (pictured on Worksheet #4), measure the distance from fulcrum to load and from a fulcrum to point of applied force (i.e., find m and n). Then compute $\frac{m}{n}$ for each.

   b) Which lever has smallest $\frac{m}{n}$?

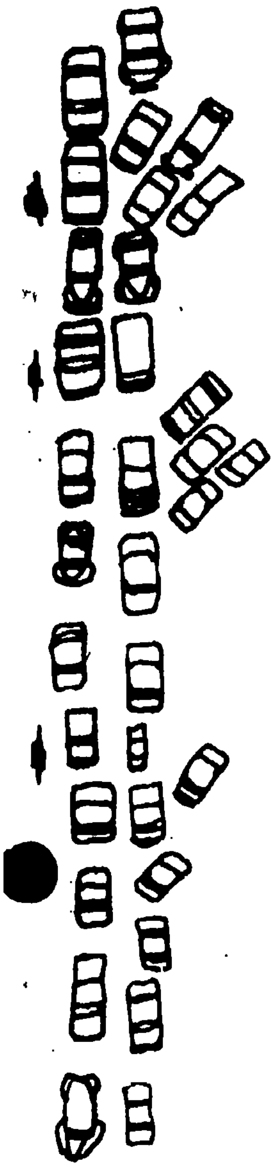
   c) Which lever uses the least force to create a 1 kg pull?

   d) Which lever moves the most distance to move its load 1 mm?

5. For each of the levers you spoke of in Question 4, describe why it would be undesireable to make them with <u>more</u> leverage than they have (i.e., make $\frac{m}{n}$ smaller).

ECO-LOGIC

Activity 13



Write one sentence about bicycles that logically follows from each mathematical fact below.

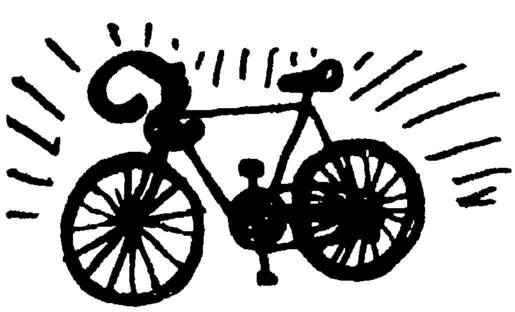
1. 90% of all automobile trips in the U.S. are 16 kilometers or less in length.

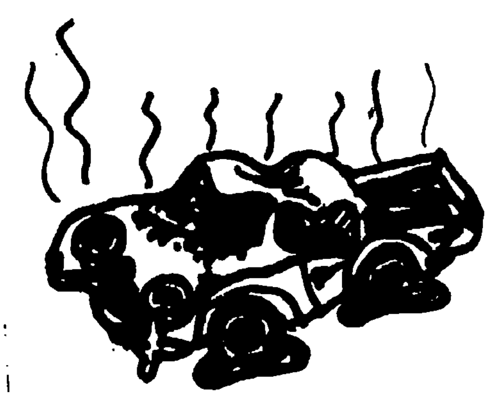
2. The average work-to-residence travel in U.S. cities is 8 kilometers, and in U.S. suburbs is 9.6 kilometers.

3. In May, 1971, according to a Gallup Poll, 81% of Americans commuting to work went by car, whereas in no other country of the world do more than 45% of the workers commute by car.

4. In the city, cars cut commuting time by only 1/3 to 1/2 while they require 370 times more horsepower than a bicycle on the average.

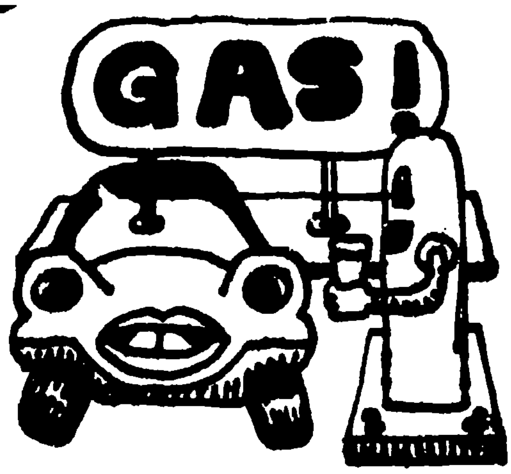
5. A good 10-speed costs about $150 and lasts ten years. An average automobile costs $2800 and lasts five years.



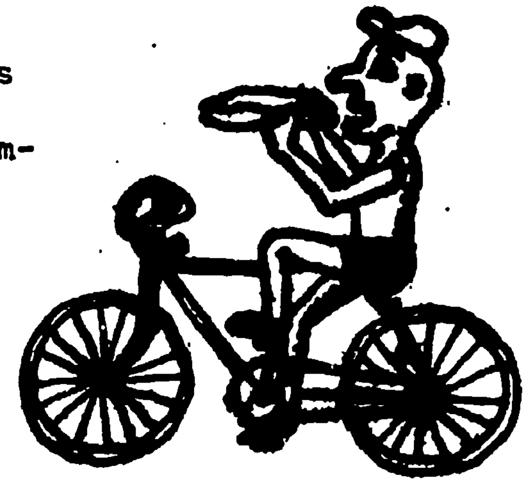


energy talk

Activity 14



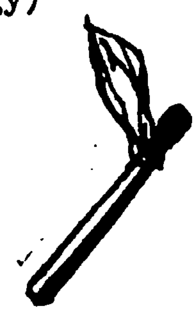
Cars use gasoline and people on bikes use food to get the energy to move. Before we can compare a car's performance with a bicyclist's performance, we have to talk about how energy is measured.



ENERGY is usually measured in terms of how much HEAT it will make. We will have to spend some time now learning about units of energy.

The calorie and the joule are two small units of heat (energy)

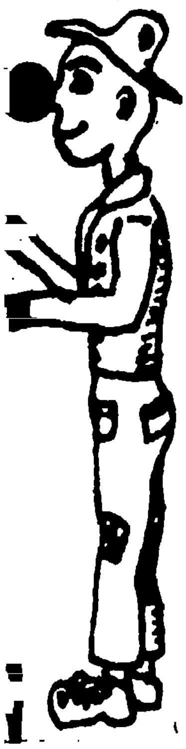
1 joule = .24 calories



1. Which is bigger, a joule or a calorie? __________
2. About how many joules are there in a calorie? __________

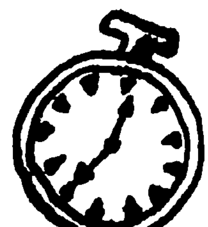
Then there are large Calories (with a capital C)

1 Calorie = 1000 calories = 4166 joules



3. Using the information on the farmer at the left, how many joules of energy does he use up on his hard day's work?

____



Now, a person who uses up 746 joules every second is working very hard, whereas one who uses up 746 joules in an hour is barely moving. So ... TIME has to be taken into account when we spend energy.

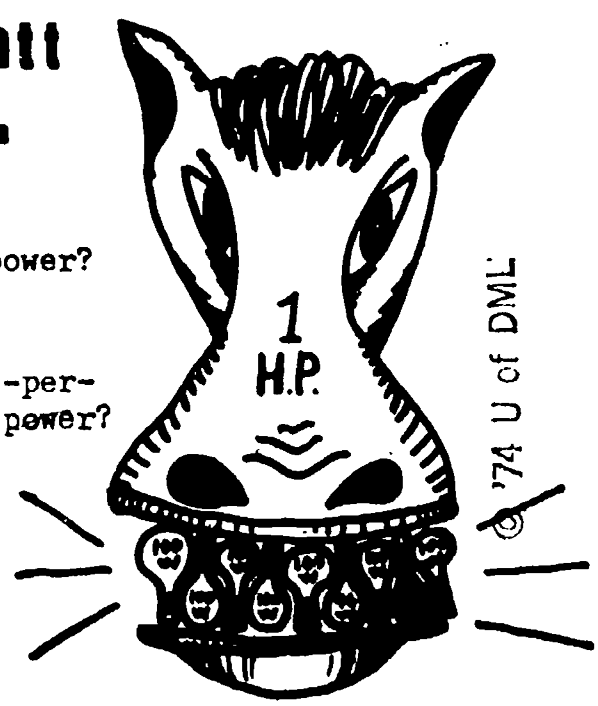
a joule-per-second is a watt

746 watts = 1 horsepower

A farmer might use up 4000 Cal in a hard day's work.

4. How many watts is 11 horsepower?

____



Some car engines can generate 300 horsepower at peak efficiency and power. They more often only need between 4 and 11 h.p. to keep a car going ... km/hr.

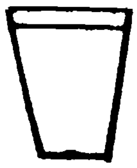
5. How many Calories-per-second is a horsepower?

____

(Hint: Give an approximate fraction.)

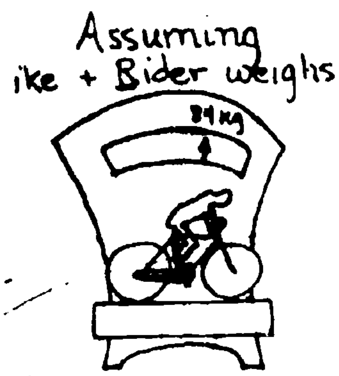
Worksheet 19

energy talk

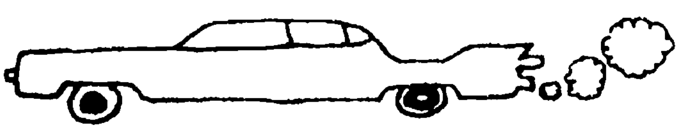


(1) A glass of whole cow's milk contains 660 calories of energy. How many joules is this? ________

If a bicyclist burns up 373 joules per second (i.e., 373 watts watts or 1/2 horsepower), how long will a glass of milk allow him to pedal? ________



(2) According to one calculation, a man on a bicycle uses 12.6 calories to travel 1 kilometer (assuming B + R = 84 kg). If he goes 24 km/hr. (a comfortable speed) it takes him how long to go 1 kilometer? ______ min. or ______ sec. Thus, our bicyclist uses 12.6 calories or ______ joules in ______ sec. This is ______ joules per second; i.e., ______ watts. Our bicyclist, therefore, is using energy about like burning a ______ watt light bulb.



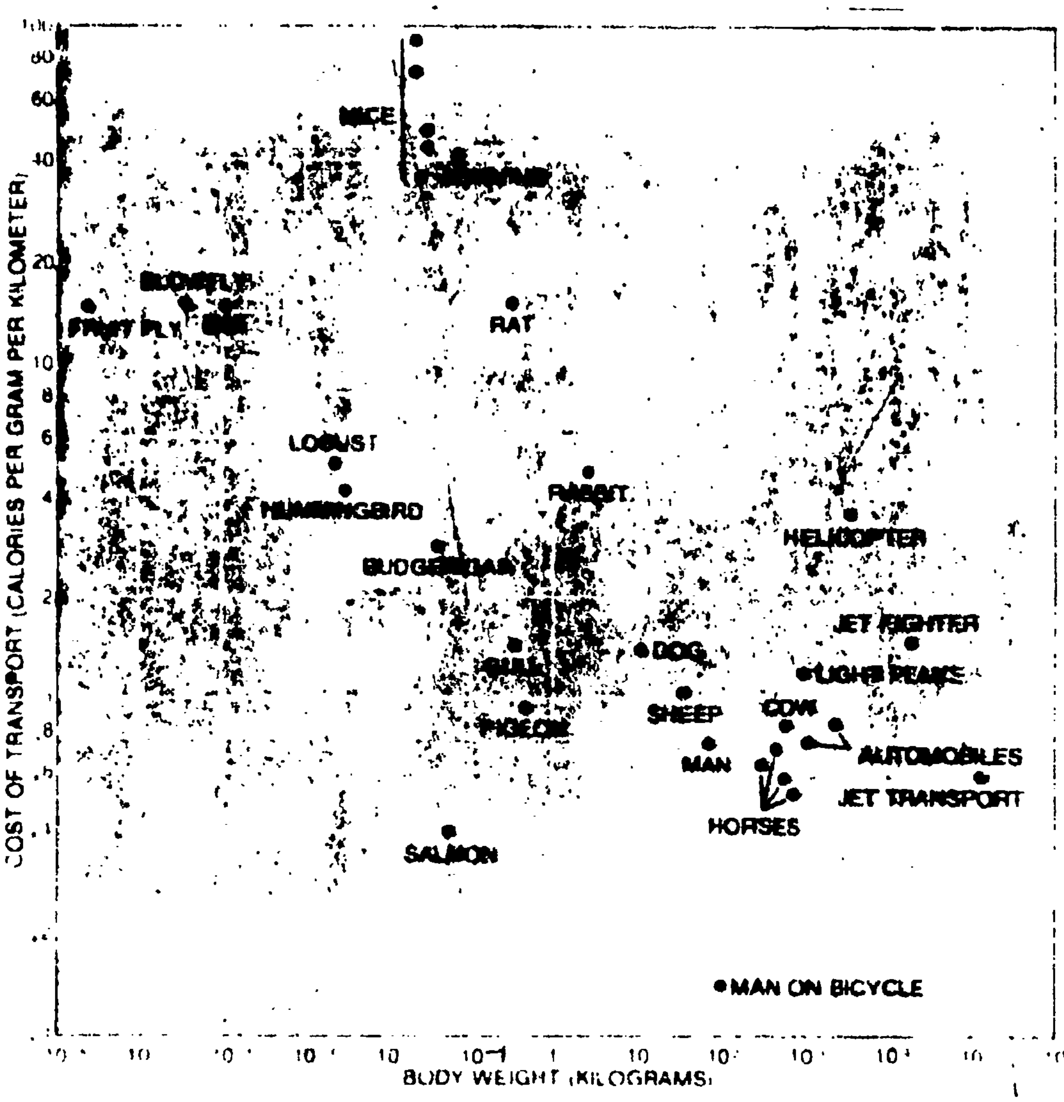
(3) A car, on the other hand, uses 1500 calories to travel 1 kilometer. Assume a speed of 48 km/hr. How long to go 1 kilometer? ______ min. or ______ sec. The car uses 1500 calories or ______ joules in ______ sec. This is ______ joules per second; i.e., ______ watts. Our car is burning ______ 200 watt light bulbs.

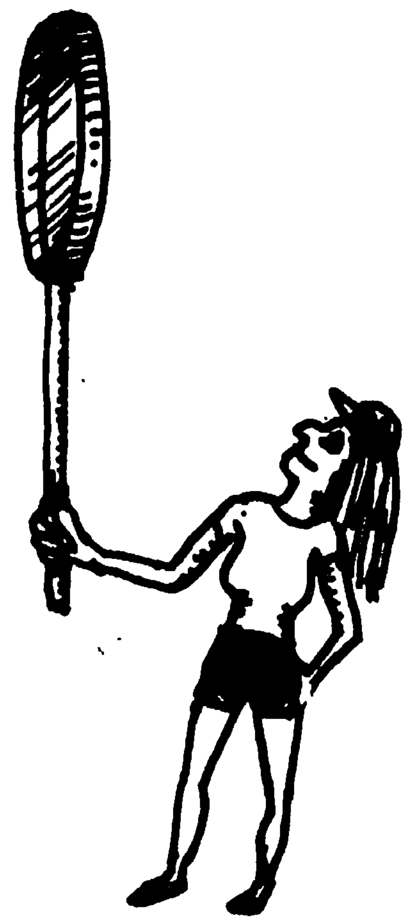
(4) Compare the answers to (2) and (3). Draw a conclusion about riding bicycles.

BIKEFFICIENCY

Activity 15

It is best that you have complete the ENERGY TALK card (#14) before this one. Examine this chart carefully.





Here are some notes and questions to help you make sense out of the chart:

$$10^{-2} = \frac{1}{10^2} = \frac{1}{100} = .01$$

$$10^{-3} = \frac{1}{10^3} = \frac{1}{1000} = .001$$

a) 10^{-4} = ___ = ___ = ___

b) What number is half way between 10^{-3} and 10^{-4}? ________

c) The further a point is to the right on a chart, the ______________ (heavier, lighter) it is.

d) The higher the point is on the chart; i.e., nearer the top, the __________ (more, less) energy it takes to move a gram of its weight a kilometer.

e) From the chart, an average dog weights ________ kg.

f) A bee weighs _____. A blowfly weighs _____. A rabbit weighs _____.

"Calories per gram per kilometer" is a unit of heat or energy necessary to transport a gram of weight over a distance of 1 kilometer. The less calories-per-gram-per-kilometer a creature uses, the more "efficient" it is said to be. List below, from the chart, the $\frac{cal}{gm\text{-}km}$ for

g) dog _____

h) large automobile _____

i) man (walking) _____

j) jet transport _____

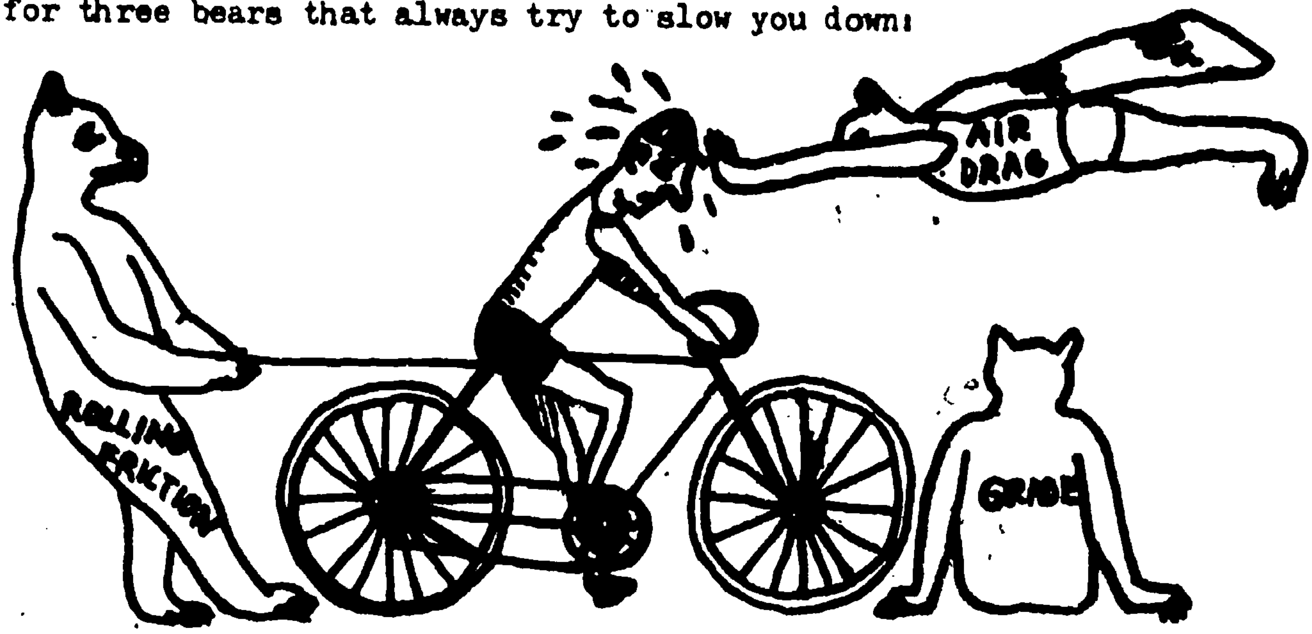
k) man on bicycle _____

l) The most efficient of all moving creatures is _________.

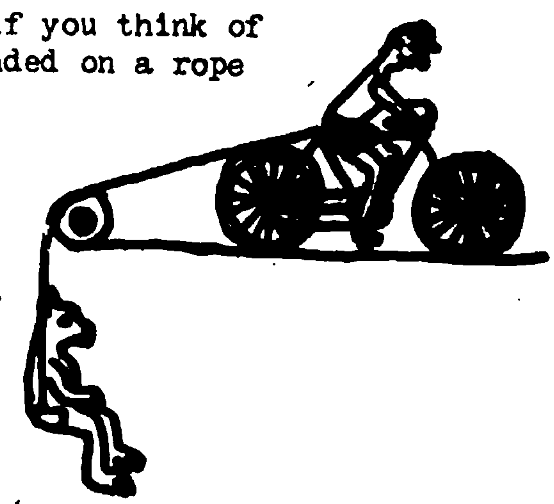
THE THREE BEARS

Activity 16

You could go forever on your bike with no work at all if it weren't for three bears that always try to slow you down:



It is easier to picture what these bears do if you think of each one as weighing so many kilograms and suspended on a rope over a pulley behind your bicycle like this:



The first bear is ROLLING FRICTION caused by rubbing of the metal parts that move on your bicycle and squishing of your tires. Here is how to calculate your rolling friction bear's weight:

$$R = C \times W$$

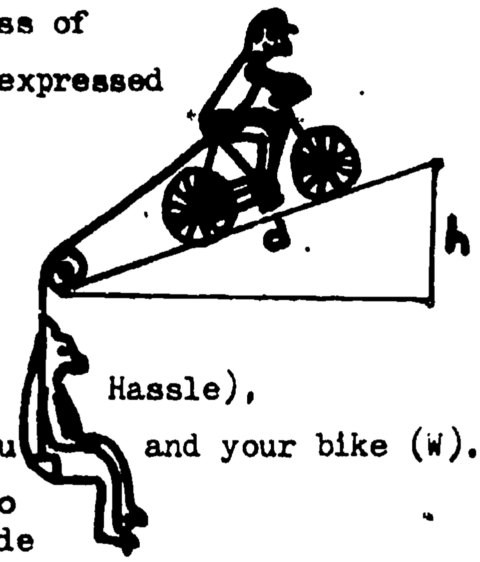
R = Rolling Bear's weight
W = Weight in kilograms of you and your bicycle (add about 14 kg to your weight)
C varies with road conditions -

- C = .01 on dirt road
- C = .004 on paved road
- C = .002 on smooth track.

1. Now, calculate your R for each kind of road condition. _____, _____, _____. Is the ROLLING FRICTIONS BEAR lighter than you expected? Remember that you are constantly lifting him as you pedal.
2. Rolling friction increases by 20% if you remove half the air pressure from your tires. What is your R for soft (1/2 pressure) tires on paved road? __________
3. Rolling friction increases by 20% if you ride a friend on your bike (It's unsafe!) Assume your friend weighs what you do and starting with the R = C x W formula, calculate R for dirt road, soft tires and friend on bike. __________

THE THREE BEARS

Activity 16 (con't)



The next bear is **GRADE**, that is, the steepness of the hill you are on. Grade is measured by this ratio expressed as a percent:

$$G = \frac{\text{Height of Hill}}{\text{Distance to Ride up}} = \frac{h}{d} = \underset{\text{(decimal)}}{.\_\_\_\_} = \underset{\text{2 places}}{\_\_\_\_.}\,\%$$

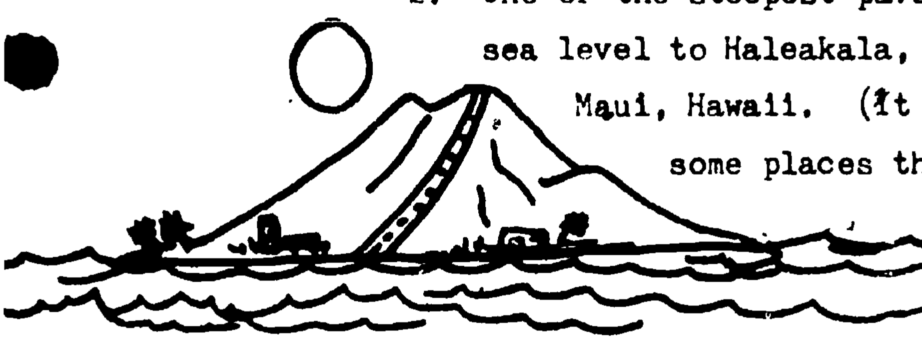
To get the weight of GRADE bear (which stands for Hassle), multiply the percent grade G by the weight in kg of you and your bike (W).

$$H = G \times W$$

(Remember to change Grade percent to decimal before multiplying.)

1. If you ride .5 km and the road rises 20 m, what is the percent grade?

____



2. One of the steepest paved roads in the world is the road from sea level to Haleakala, a volcanic crater on the island of Maui, Hawaii. (It has been bicycled!) It is steeper in some places than in others, but find its <u>average</u> percent grade by using these figures:
   Height of crater above the sea: 3700 m
   Length of road: 80 km

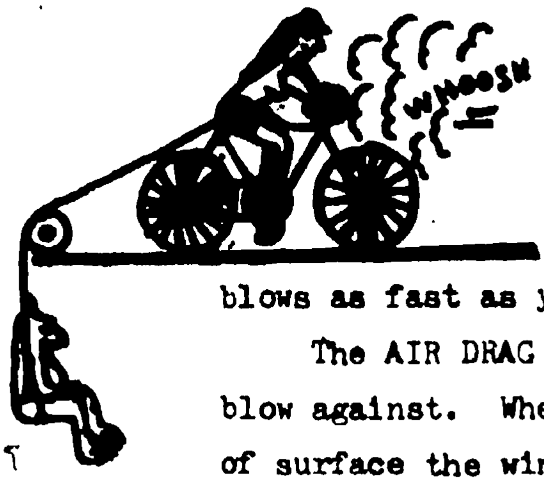
3. A grade of 7% is considered very steep for a paved highway. If you cycled 11 km on such a road, how much altitude (in meters) would you gain? __________ What is the weight of the Grade Bear on such a road? __________

4. (For the Brains) If you and your bike weigh 80 kg while your friend plus bike weighs 70 kg, find how steep a grade your friend must ride up to have a Grade Bear that weighs as much as yours weighs when you ride up a 5% grade.

Activity 16 (Second continued page)

THE THREE BEARS

The last bear is AIR DRAG. You all know that riding into the wind slows



you down. Even if the air is still and you ride at 35 km/hr., that is like a 35 km/hr head wind. On the other hand, if you had a 20 km/hr trail wind and you are riding 35 km/hr., then your head wind is 15 km/hr. The <u>head wind</u> is what slows you down. If the wind blows as fast as you ride, there is no AIR DRAG.

The AIR DRAG on you depends on how much surface the wind has to blow against. When you ride bent down ("tucked") you reduce the amount of surface the wind hits so you reduce the weight of the AIR DRAG BEAR.

Here is the formula for calculating Air Drag A:

$$A = .07 \times C \times S^2$$

S is the speed of the <u>head wind</u>. S must be <u>squared</u>; i.e., multiplied times itself.

C is the cross-sectional area the wind sees when it blows against you. It is expressed in square meters. Here are some values to use for C:

CROSS SECTIONAL AREA

Average sized rider sitting upright	.35 square meters
Small rider sitting upright	.30 square meters
Average sized rider in tucked position	.20 square meters
Small rider in tucked position	.15 square meters

1. If a head wind of 10 km/hr is blowing while you ride 25 km/hr, how much air drag can you save by riding in a tucked instead of upright position? ______________

2. In still air, coasting 30 km/hr, how much less drag will a small rider in tucked position have than an average rider sitting upright?

   ____

3. Calculate the total drag from the three bears for an average sized person weighing 60 kg, with a 15 kg bike, riding a dirt road with a 2% grade and going 10 km/hr against a 6 km/hr headwind, riding in an upright position and having tires only half inflated. ________

4. After studying the three bears, which one is the most likely to slow you down? ____________